COMMITTEE OF THE PRIVY COUNCIL FOR
THE ORGANISATION AND DEVELOPMENT OF
AGRICULTURAL RESEARCH

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL

For the Period July 1931—30th September 1933

Presented by the Lord President of the Council
to Parliament by Command of His Majesty
September 1934

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THE COMMITTEE OF PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH

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REPORT OF THE

COMMITTEE OF THE PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH

For the period 28th July 1930 to 30th September 1933

TO THE KING'S MOST EXCELLENT MAJESTY IN COUNCIL.

MAY IT PLEASE YOUR MAJESTY,

We, the Lords of the Committee for the Organisation and Development of Agricultural Research of Your Majesty's Privy Council, appointed by Your Majesty's Order in Council dated the 28th day of July, 1930, humbly submit to Your Majesty a Report of our proceedings from the 28th day of July, 1930, to the 30th day of September, 1933.

On the 29th day of June, 1931, Your Majesty was pleased, by and with the advice of the Privy Council, to approve the Draft of a Charter for creating a Body Corporate, under the style and title of " The Agricultural Research Council ", and to order a Warrant to be prepared for Your Majesty's Royal Signature, for passing under the Great Seal a Charter in conformity with the said Draft, which Charter was passed under Your Majesty's Sign Manual at Westminster the twenty-third day of July, 1931, in the twenty-second year of Your Majesty's reign when Your Majesty's Letters were made Patent. The Charter is set forth in the first Appendix to this Report.

By Section 13 of the Charter, the Agricultural Research Council shall at all times be responsible to and shall, subject to the provisions of the Charter, comply with such directions as may from time to time be given to them by the said Committee of the Privy Council.

By Section 2 (c) of the Charter, the Agricultural Research Council is authorized to accept, hold and dispose of money or other personal property, and by Section 4 this power is extended to lands and other real property. Thus the Council can accept and use for its purposes gifts or bequests whether of money or land. It is hoped that benefactors, interested in agricultural research, will make use of this provision.

To guide the Agricultural Research Council in its relations with the Agricultural Departments, the Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland, and with the Development Commission, a Provisional Note on Administrative Arrangements was given to the Council at its inception by the Right Honourable Lord Parmoor, then Lord President of Your Majesty's Council, and is reproduced in Appendix II to this Report.

Since the formation of the Agricultural Research Council, during the period under review, the Committee of the Privy Council for the Organisation and Development of Agricultural Research has met twice. At these meetings the Committee received detailed Reports of the work of the Agricultural Research Council, and approved the arrangements proposed for its financial and other administration.

After consultation with the members of the Agricultural Research Council and the President of the Royal Society, the said Committee of Privy Council appointed the Right Honourable Lord Richard Cavendish, one of the members of the Agricultural Research Council, to be Chairman thereof.

With the approval of the Lord President of the Council and after consultation with the President of the Royal Society the Agricultural Research Council appointed Sir William Cecil Dampier to be Secretary of the Council, and the Committee of Privy Council for Agricultural Research appointed Sir William Dampier to be also Secretary of that Committee.

The Agricultural Research Council was charged in 1931 by the Lord President of the Council, in the Provisional Note on Administrative Arrangements, with the duty of giving advice on agricultural research to the Agricultural Departments and to the Development Commission, which between them in that year were responsible for the expenditure, with the authority of the Treasury, of a total amount of about £390,000 (excluding capital sums) on agricultural research, including the specialist advisory services for farmers.

By far the largest part of this sum is found from a single source, the Development Fund, from which advances are made with Treasury approval on the recommendation of the Development Commissioners either to or through the Agricultural Departments.

A sum of £5,000 was provided in 1931 from the Development Fund and, in addition, such sum not exceeding £1,500 as might be required for the payment of honoraria and such expenses of the Agricultural Research Council as might be be approved by the said Committee of the Privy Council and the Lords Commissioners of Your Majesty's Treasury for the remainder of the year.

The aforesaid sum of £5,000 was placed at the disposal of the Agricultural Research Council to be expended on their own authority for the encouragement of agricultural research, any savings thereon to be non-surrenderable. In view of the financial crisis, the Agricultural Research Council restricted its expenditure, and asked for no research grant from the Development Fund in 1932. In 1933 the Lords Commissioners of Your Majesty's Treasury, on the recommendation of the Development Commissioners, placed a further amount of £6,000 at the disposal of the Agricultural Research Council for research purposes, and a further sum of £2,000 (with an equivalent appropriation-in-aid from the Development Fund) was included in the estimates of the two Agricultural Departments, to be expended by those Departments in consultation with the Council and the Development Commissioners. At the same time, the annual grant for administrative expenses of the Council was raised from £3,000 to £3,275. The extreme economy with which the work of the Agricultural Research Council is carried on is made possible by the hospitality of the Development Commission as regards office accommodation and other facilities, and by the close collaboration of the administrative and clerical staffs of the two bodies.

The initiation of a new body such as the Agricultural Research Council inevitably involves administrative problems requiring careful and unhurried consideration, especially when the new body necessarily stands in close relation to other pre-existing bodies. It was only after prolonged examination of those problems by Committees appointed by the Cabinet that the functions of the Council were defined.

Firstly, the Agricultural Research Council was designed to complete the Scientific organisation for the supervision of subsidised research, other sections of which were already managed by the Medical Research Council and the Department of Scientific and Industrial Research. The Agricultural Research Council keeps in close touch with its sister Councils. In Section 8 of the Charter of the Agricultural Research Council it is required that in the appointment of persons to be members of the Council regard shall be had, so far as possible, to the desirability of securing at all times that one member shall be a person who is also a member of the Medical Research Council, and one other member shall be a person who is also a member of the Advisory Council for Scientific and Industrial Research. Of the first appointed members of the Agricultural Research Council, Dr. J. A. Arkwright is also a member of the Medical Research Council, and Dr. E. J. Butler is also a member of the Advisory Council for Scientific and Industrial Research. Further, by the direction of the Lord President, the three Secretaries meet at regular intervals for discussion of questions of joint interest, and informal conversations often take place between these meetings; moreover, joint Committees are appointed when further enquiry is necessary on matters of common concern.

The Secretary of the Department of Scientific and Industrial Research is assessor to the Agricultural Research Council and the Secretary of the Agricultural Research Council is assessor to the Advisory Council for Scientific and Industrial Research. The Secretary of the Medical Research Council, which does not appoint assessors, is free to attend all meetings of the Agricultural Research Council. Representatives of the Treasury, the two Departments of Agriculture and of the Development Commission receive the Agenda papers for Council meetings and are invited to be present during the discussion of business which particularly concerns their Departments.

Secondly, while the Medical Research Council and the Department of Scientific and Industrial Research have themselves built up and now control the Research Institutes and isolated researches for which they are responsible, when the Agricultural Research Council was founded there was already in being an extensive organisation for agricultural research, initiated under a scheme framed by the Development Commissioners in 1911, and since then extended in collaboration with the two Departments of Agriculture, who are responsible for the administration of the large Development Fund advances provided annually for the maintenance of this organisation.

In the Lord President's Provisional Note on Administrative Arrangements, it is laid down that, while the general relationship of the Agricultural Departments with Agricultural Research Institutes, University Departments of Agriculture and Agricultural Colleges is to continue unchanged, the Agricultural Research Council is to give criticism and advice on research grants and programmes, though the expenditure for research services hitherto administered by the Agricultural Departments and borne on their Votes is so to remain, and Parliamentary responsibility for agricultural research remains with the Ministers responsible for agriculture. On the other hand, the administrative expenses of the Agricultural Research Council are borne on the Vote for Scientific Investigation, etc. (Class IV, 9), under the Parliamentary responsibility of the Lord President of the Council, and the special research grant (£5,000 in 1931 and £6,000 in 1933) drawn from the Development Fund, a grant which also now appears on that Vote, is to be spent on their own authority by the Agricultural Research Council under the general direction of the Committee of Privy Council, the Departments of Agriculture being consulted on proposals affecting Institutions for which the Departments are responsible. It is further laid down in the Note that the Council shall act as the scientific advisers of the Development Commissioners. The dividing line between expenditure financed direct by the Agricultural Departments, and expenditure financed by these Departments by means of grants from the Development Fund, is to be retained.

It is clear that the relations of the Agricultural Research Council with these bodies—on the one side with the Medical Research Council and the Department of Scientific and Industrial Research, and on the other with the Agricultural Departments and the Development Commission—make the administration of its work both complicated and difficult. Indeed, it could only be carried on successfully with the general good will of all concerned.

With regard to the method of payment of grants from the research fund of the Agricultural Research Council, the Council, at the request of the Treasury, has agreed for the sake of uniformity to make use of the existing financial and administrative machinery of the Departments of Agriculture for the present, whenever grants are made to Research Institutes chiefly maintained by means of annual advances from those Departments, with appropriations in aid from the Development Fund.

The Report of the Research Council to the Committee of Privy Council, appended hereto, shows that the Agricultural Research Council began its work by initiating, with the encouragement of all the Departments concerned, a comprehensive survey of the agricultural research now being carried on in Great Britain, especially in those Institutes partly or wholly supported by public funds. In order to facilitate the work, six standing Committees of the Council were formed.

The list of these Committees, and the arrangements for joint action by the Committees concerned with researches on animals and on soils and plants respectively, are described in the Council's Report.

During the time now under review, visits were paid to 22 Research Institutes or other research centres either by one of these Committees, or by two or more of them conjoined, sometimes followed by visits of special *ad hoc* Sub-Committees, including in their membership eminent experts from outside the Council.

Some of these visits were arranged in the normal course of the Council's general survey of agricultural research, but others were specially undertaken in order to answer quickly appeals for advice made to the Council by the Ministry of Agriculture, the Scottish Department of Agriculture or the Development Commission. Special reports have been rendered in answer to such questions.

Among these special reports we may mention firstly one containing the results of a careful enquiry on the past history and future prospects of the research on Foot-and-Mouth Disease which, for the last ten years, has been carried on under the direction of a Committee of the Ministry of Agriculture and Fisheries. The Agricultural Research Council formed a special expert Committee to make this enquiry. As will be seen below, the Committee reported that it was convinced that excellent work, resulting in definite advances in knowledge, had been done. While it could not be said with certainty that any preventative measures for this disease, such as an effective vaccine, were likely to be discovered immediately, such measures, based on the results already reached, were certainly a possibility of the future. The Committee also made recommendations for the future scientific administration of the Foot-and-Mouth Disease Research Station.

Again, at an early stage of its general survey, the Agricultural Research Council came to the conclusion that at the present time the most urgent subject of inquiry for the economic well-being of the British farmer was that of animal disease. This conclusion was strengthened when Your Majesty's Government foreshadowed an agricultural policy which involved an increase in the animal population of the country, and a consequent additional risk of the spread of certain infectious, contagious, or otherwise communicable diseases.

To meet the situation, the Agricultural Research Council, after consultation with veterinary experts, resolved to institute an immediate enquiry into the present state of knowledge regarding the most important and most dangerous of such diseases and the work in progress upon them, and formed seven special Committees, most of them consisting mainly of experts from outside the Council, to undertake the work.

Reports from these Committees are now coming in. Some of them contain recommendations for immediate research, and in certain cases the Agricultural Research Council has either itself allocated funds or made arrangements for the necessary provision through a Department of Agriculture, and authorised the appropriate Committee to pass from advisory functions to those of general co-ordination. The Committee of Your Majesty's Privy Council hopes that thus the Agricultural Research Council may do its share in making possible the immediate agricultural development which Your Majesty's Government has in mind.

In the course of their special enquiries into certain animal diseases, the Council has not only had valuable assistance from, and worked in close co-operation with the Agricultural Departments, but has also had the advantage of the special knowledge and resources of the Imperial Bureaux.

One of the most important functions which the Council is called upon to perform is to advise the Agricultural Departments and the Development Commissioners annually on the programmes and estimates of the Agricultural Research Institutes. This is a duty which the Council has been willing to perform only after its members have gained knowledge, usually by personal contact, of the Institutes concerned.

The Council is also asked to advise on the award of Scholarships and Studentships, and on the making of grants for special investigations.

These many and varied activities involve a large amount of work and of expert knowledge both of practical agriculture and of the sciences which concern it. The Agricultural Research Council has represented to the Committee of Privy Council that an increase in their number is desirable. The original number provided by the Charter is thirteen, to fall to twelve at the first vacancy. No vacancy has yet occurred.

Since the end of the period under review, Your Majesty has been graciously pleased to issue a Warrant for the amendment of the Charter, so that the number of members of the Agricultural Research Council may in future be not less than twelve or more than fifteen.

In conclusion, the Committeee of Privy Council desires to place on record its high sense of the value of the work done by the Agricultural Research Council during the difficult initial stage of its activities.

The subjoined Report of the Council shows the immense amount of inspection accomplished and advice given, while the Introductions to the various sections, written for the most part by one or other of the eminent men of science who are members of the Council, supply an authoritative account of the present state of those branches of knowledge which underlie the practice of agriculture.

STANLEY BALDWIN,
Lord President.

WM. CECIL DAMPIER,
Secretary of the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

1st August, 1934.

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL

For the period July 1931 to 30th September 1933

To the Lords of the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

May it please Your Lordships,

The Agricultural Research Council beg leave to submit the following Report upon their proceedings from their incorporation in July, 1931, to 30th September, 1933.

The constitution of the Agricultural Research Council, in so far as it works under a Committee of Privy Council, resembles that of the Medical Research Council and that of the Department for Scientific and Industrial Research, and these three allied bodies act in close collaboration.

The functions of the Agricultural Research Council are both administrative and advisory. It has control of a grant made periodically from the Development Fund—£5,000 in 1931 and £6,000 in 1933—for the initiation or encouragement of special researches. It also advises the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland and the Development Commission on the scientific aspects of the agricultural work going on in Research Institutes and elsewhere at a total cost in 1931 to the State of some £390,000.

The relations of the Council with the Bodies that it advises are laid down in the Lord President's Note on Administrative Arrangements set forth in Appendix II. It will be seen that these relations must be both complex and continuous. The Agricultural Research Council desires to offer its sincere thanks to the staffs of the other bodies who have met the occasional inevitable divergences of view in a friendly and helpful manner.

When the Council was established, it was intended that the research work going on in the various Institutes should gradually be developed and increased under the superintendence of the new Council. Unfortunately, before the Council began its work, the financial crisis supervened; it became clear that no additional expenditure could be contemplated, and that, wherever possible, savings must be effected. During this, its initial period, therefore, the Agricultural Research Council had to bear the need for economy continually in mind.

I. PROCEDURE

The work of the Agricultural Research Council covers a large number of different practical subjects, based on an even larger number of underlying sciences. It was therefore found necessary to form six standing Committees, each to deal with one broad division of the Council's activities:

Animal Diseases (Chairman—Sir Merrik Burrell).
Animal Nutrition and Breeding (Chairman—Sir Frederick Gowland Hopkins).
Dairying and Animal Products (Chairman—Professor E. P. Cathcart).
Plants (Chairman—Sir Daniel Hall).
Soils (Chairman—Sir Thomas Middleton).
Agricultural Economics (Chairman—Mr. Joseph Duncan).

The composition of these Committees is given in Appendix III.

The standing Committees were given power to form Sub-Committees to deal with particular subjects, and on the Committees and Sub-Committees experts, specially conversant with those subjects, have been appointed from time to time from outside the Council.

The Committees and Sub-Committees meet at irregular, though generally at frequent intervals, as often as their work demands. The Agricultural Research Council itself sits about once every three months, unless special or urgent business calls for other meetings. Including the Council, Committees, Sub-Committees and Conferences, just over one hundred meetings were held during the period under review.

The Committees which deal with animals soon found that the subjects of animal health and animal nutrition and breeding were so nearly allied that it was convenient for the two Committees concerned with those subjects to meet together, and that then they included all members of the Committee on animal products. Similarly the Committee on plants found points of contact with the Committee on soils, and for many purposes these two Committees have acted together. Thus Sub-Committees have usually reported to joint Committees either on animals or on soils and plants. This course has helped to keep a large number of members of the Council in touch with the special work of the numerous Sub-Committees.

The first task of the Agricultural Research Council was to examine the work in progress at the different centres of research. With this object a complete survey of the Research Institutes was planned. But certain urgent questions arose on which the Agricultural Departments or the Development Commission desired the advice of the Agricultural Research Council, so that the normal course of the survey had sometimes to be interrupted.

When the work of an Institute is to be examined, the most usual procedure has been to hold a Conference, either at the Institute or in London, with the Director or other representatives of the Institute, and to arrange first for one or more of the standing Committees of the Council, and then for a small Sub-Committee, which could study thoroughly the details of the work, to visit the Laboratories, meet the members of the staff and see the work in the field.

The Sub-Committee reports to the appropriate Standing Committee or Joint Committee, which in turn, reports to the Council. As regards its general work, such as the survey, the Council submits Reports to Your Lordships, sending for information copies to the Agricultural Departments and the Development Commission as well as to the Treasury. When the Council Report is an answer to a question asked, the Report is sent to the Body asking for it, and a copy, for information, to Your Lordships' Committee of Privy Council.

One of the Agricultural Research Council's most important duties is to advise the two Agricultural Departments and the Development Commission each year on the research programmes and estimates of all the Institutes, as well as on the award of Research Scholarships and Studentships.

When the Council uses its other powers, and proposes to make a grant from its own funds to aid a special research, it first seeks the opinion of the Agricultural Department concerned, and gives weight to that opinion in making its final decision.

The present Report covers the first two years of the activities of the Agricultural Research Council. The Council's general survey of agricultural research was not completed during this time, and the report on it can only be finished next year. Nevertheless it was thought well to draft this first Report to give an outline of all the work going on, as well as a more detailed description of that already examined more fully.

Each section of the Report, dealing with one great division of agricultural research, is preceded by an account of the recent history and present state of knowledge of that subject. Most of these introductions have been written by members of the Council specially conversant with the sciences involved. It is therefore hoped that this Report will not only serve as a foundation for future Annual Reports, but be found of permanent value as an account of agricultural science in Great Britain in the year 1933.

II. THE ECONOMIC OUTLOOK

INTRODUCTION

In 1931, when the Agricultural Research Council was founded, and during the two years covered by this Report, much the most important factor in practical agriculture was the economic—the costs of production of agricultural produce on the one hand, and the income obtained by its sale, involving both prices and output, on the other.

The subject of Agricultural Economics is but one aspect of Economics in general, though agriculture, like other industries, has economic peculiarities of its own. The post-war problem of the British farmer was to meet falling prices and increased wages, high compared with those of pre-war times, by improving his management, increasing the yield of his land, and shifting his production, as far as might be, to higher priced and perishable goods.

British industry in general was faced with the alternatives of lowering costs of production, including wages, to meet the deflation in prices, and trusting the consequent fall in retail prices to readjust real earnings, or to look for a rise in wholesale prices, produced over the whole field by an automatic revival in world trade, or else by monetary reflation, or in special commodities by tariffs or quotas. The rigidity of the British wage-system made impossible a lowering of wage-rates sufficient to balance the fall in prices, even if that method were desirable; world trade did not revive, and the monetary opinions of the Financial Authorities stood in the way of reflation. We have thus been brought to an attempt to raise special prices by Marketing Boards, restriction of imports and other forms of protection, with all their complicated repercussions on other trades.

The policy of " controlled industry " was probably inevitable in present circumstances, at all events as a temporary expedient, but we must not overlook the fact that it involves a revolution in economic machinery. In the *laisser faire* system, even when modified by protection in many countries, the rise and fall of prices produced an automatic adjustment of supply and demand, and an elimination of the inefficient, though it was less rapid in its effects in agriculture than in most other industries.

The new policy abolishes, or at all events much diminishes, this automatic adjustment. It seeks to fix prices artificially according to costs of production, though such costs change from time to time, and even in one year, have a high coefficient of variation.* It seeks to control supply by regulating markets or even production, and, in so doing, runs the risk of lowering demand, checking initiative, and giving the marginal or even more inefficient producer a vested interest in present, perhaps obsolescent, methods.

It is clear that the replacement of an automatic by a deliberate, "planned" economy will produce secondary effects in the industry under discussion, and repercussions in other industries, which will give a very wide scope for economic investigation, and, in the national interest, will need most careful watching by independent observers. Especially is this the case with agriculture, which deals with the necessary food supply of the nation. Agricultural economists have before them much work, which will be more effective if co-ordinated.

Whereas after the Napoleonic wars the burden of agricultural depression fell largely on the labourer, immediately after the recent war the labourer was safeguarded by Wages Boards and Committees, and his economic standard is higher than before 1914. The burden has fallen primarily on the farmer, and, where he is a tenant, through him on the landowner, who has to face greatly increased costs in the repair of buildings and higher taxation, with falling rentals.† Some economists hold that these increasing burdens will make the existing system of English land tenure, however beneficial it may have been in the past, impossible in the future.

To understand agricultural economics, it is necessary not only to have some knowledge of farming practice, but to study fundamental economic principles, especially such parts of them as the theory of prices.

The course of agricultural prices during and after the war conforms so closely to the course of wholesale prices in general that the chief underlying causes must be the same.‡ The 1920-23 fall in prices was world wide, as was the accompanying depression. Thus, speaking broadly, the problem of agricultural prices is only one aspect of that of world prices in general. By the theory of money, set forth in any text book, the number n of business transactions in a given time, multiplied by the average price p, at which each transaction is carried out, must clearly equal the amount c of money (including cash and credit) used, multiplied by the number of times it is turned over, i.e., its velocity of circulation, v. That is:—

---

* The spread in costs in the case of recent investigations on wheat ranged, even in one District, from £4 10s. to £12 10s. an acre.

† See Orwin and Peel, The Tenure of Agricultural Land, Cambridge, 1925; Dampier, Presidential Address to the Agricultural Economics Society, 1930.

‡ See R. R. Enfield, The Agricultural Crisis 1920–23, London, 1924; and Report of the Committee on the Stabilisation of Agricultural Prices, London, 1925.

$$np = cv, \text{ or } p = \frac{cv}{n}$$

Thus scarcity is not the only cause of a rise, nor is plenty the only cause of a fall in prices; they must be correlated with the amount of money available and its velocity of circulation.

History shows that there are two types of periodic change in prices. Firstly, we see the shorter waves of the trade cycle, normally with a period of some eight to ten years. These waves are probably due to changes in all the terms of the quantity equation—monetary, industrial and psychological factors all being involved. The second change is a long, tidal drift up or down, lasting perhaps for twenty, perhaps for two hundred years, and dependent chiefly on the total amount of money available. When money was based on gold, the opening of new gold fields—say those of Australia and California about 1850—produced a gradual rise in world prices and agricultural prosperity, and a shortage of gold—such as that due to the demand for Central Bank reserves from 1873 onwards, when many countries adopted the gold standard—put down prices and brought about depression.*

The depression during the last quarter of the nineteenth century is usually assigned to overseas competition alone. But that competition was chiefly confined to wheat, and its results are shown by the additional fall in wheat prices over the fall for agricultural produce in general. While the general agricultural index number fell between 1875 and 1896 approximately in the ratio of 3 to 2, about the same as the average fall in all wholesale commodities, wheat fell approximately in the ratio of 2 to 1. Overseas competition, important in the one case of wheat, was, even in that case, only part of the cause. The fall in other agricultural prices was due to the same causes as that in wholesale commodities in general, and all indications suggest a monetary factor as the most effective.

Now the rise and fall of prices during and after the 1914-18 war can be traced to similar monetary influences—first inflation and then deflation—though we must not forget that short-term cyclic changes, due to many factors, have come in to complicate long-term monetary effects.

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* See, for instance, Layton's History of Prices.

These investigations on the changes during and immediately after the war throw light on the more complicated phenomena of the world-wide financial catastrophe of 1930-33. Speaking broadly, the agricultural crisis must be looked on as a part of the general dislocation of trade and industry. Probably the general crisis depended on many causes. Among them may have been unwise foreign lending, especially by the United States, lending suddenly curtailed to support a Stock Exchange boom. This restriction made debtor countries, otherwise dependent on exports rapidly falling in price, unable to buy goods in exchange. The slump which followed the American boom intensified this destruction of purchasing power. The concentration of gold in Paris and New York diminished the reserves elsewhere, and helped to curtail available currency and credit at the critical moment, and, when money again became cheap, the slackening in trade had meanwhile decreased its velocity of circulation. The fall in prices, that is, the increase in the commodity value of money, made more burdensome all debts, whether public or private, and thus increased the difficulties of industry.

Since in a depression there is usually plenty of idle money, the first remedy is to get business accelerated or restarted and money into circulation—to increase v in our equation. When v reaches a normal and steady value, when, that is, business is proceeding at a healthy rate, the price-level will depend on c, the total amount of cash and credit available, and if c be insufficient, prices fall and the growth of business is checked. Thus the amount of money should be increased as business expands, or the crest of each wave of prices in the trade cycle will be lower than the last, and the general long term trend be downwards, with a depressing effect on industry.

In 1931, a financial crisis in London forced Great Britain to abandon the gold standard, and depreciated the gold value of the pound. Its value in commodities fell also, that is, prices rose. For the time, at all events, the situation was eased, though prices in sterling soon began once more to follow the downward course of those measured in gold. The causes of this indirect connexion with gold deserved more study than they received.

Such were some of the many factors which produced the financial and commercial crisis. And agriculture shared the difficulties of industry in general. But these general considerations must be supplemented by a more detailed investigation of the special factors which concern agriculture in particular.

During the war, the dislocation of demand and supply of foodstuffs caused great local increases in production in some countries, so that, when peace returned and old sources of supply once more became available, the loss in purchasing power which many peoples suffered led to a failure in the demand for such products as wheat compared with the supply. Moreover, many countries tried to counteract the fall in prices by measures which, however effective locally, increased production and so intensified the fall in world prices. It is this difficult position, complicated by the measures taken in the attempt to amend it, that agricultural economists have to take into account at the present day.

The methods of applying economic investigation to agriculture take many forms. In the first place, the farmer's turnover is very slow; he spends money on ploughing and sowing many months before harvest. An appreciation of this fact led to the first quantitative measurement of an " economic lag " in any industry, and an explanation of the special vulnerability of agriculture, and especially arable farming, to a fall in prices.*

The " economic lag " is the weighted average of the times before the sale of produce at which a farmer incurs his costs. On a light-land, sheep and corn farm in East Anglia, the " economic lag " worked out at 14 months, an interval long enough to see a large increase or decrease in the value of the produce according as prices are rising or falling. When prices are changing fast, arable farmers make big profits or big losses. On a West Country grass-land dairy farm, the " economic lag " proved to be 7 months—a less dangerous spread between payments and receipts.

Three other methods of studying farming operations have been used by agricultural economists. The first is the taking of costings—the estimation of the cost of growing any one crop, wheat, it may be, or sugar beet. A comparison of an individual farmer's costs with the average, or with those of specially skilled agriculturists, gives him a useful practical guide to improvement. A certain amount of full costing is necessary as an instrument of research and as a guide to the economic adviser, but the variation in costs is often very wide, and the application of the results, whether as a guide to management or as material for price fixing, is probably limited to farms on a large enough scale to be departmentalised. Indeed the possibilities that exist for the skilful use of by-products and of slack times of labour on mixed farms make " costs of production " an uncertain quantity and a dangerous guide to political action. Secondly, the collection of large numbers of farmers' financial accounts, such as those kept for purposes of income tax returns, yields information on the general economic results of a given type of farming, less detailed, but more easily obtained than that given by costing. One of the dangers of error here arises from the fact that farmers who keep accounts are a selected, and therefore a non-representative sample of farmers in general. Thirdly, a survey, farm by farm, in representative areas, with friendly cross examination of each farmer, chiefly on the volume of his purchases and sales, often enables the enquirer to draw up approximate financial accounts for each of the farms visited, and thus to establish average results, with the accuracy appropriate to large numbers of somewhat uncertain data. This process sometimes leads to the discovery of enterprising farmers who are breaking away from the methods of the crowd, and striking out on lines of their own. The intensive study of their procedure and results, or those of other better known pioneers, may give most useful additions to agricultural knowledge.

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* Dampier, Economic Journal, December, 1925; Politics and the Land, Cambridge, 1927.

While the price level is falling, it is difficult for any industry, and especially difficult for agriculture, to make profits. But once stability is reached, even at a low level, adjustment becomes more possible. It must be remembered that it is not merely prices, but the whole monetary income of a farm, depending on output as well, that is involved in profit or loss. Hence comes the importance of agricultural research and of its practical application by progressive farmers. Skilful management and a larger output, especially of higher grade and perishable products, may balance a low range of prices, and make the difference between success and failure. It is fortunate that the farm policy thus indicated will tend also to increase the supply of those foodstuffs—meat, milk, eggs, vegetables, etc.—that contain high proportions of digestible proteins and vitamins, and are needed in larger quantities for the improvement in national diet which returning prosperity and sounder knowledge will make possible.

THE ORGANISATION OF WORK ON AGRICULTURAL ECONOMICS

The application of general economic principles to agriculture, and still more the use of agricultural facts to establish new economic principles, is appropriate to the isolated worker in a University or elsewhere. But the importance of the economic data of actual farming to the farmer himself led the Ministry of Agriculture and Fisheries in 1929 to establish an Economics Division. A Marketing Division had been set up in 1924. Both of these Divisions issue occasional Memoirs on special subjects and periodic reports on prices, output and other data. Though the scale of these departments is very small compared with those in some other countries—for instance, in the United States—they produce results of great value.

In order to develop research in this subject, previously neglected in Great Britain, in 1913 the Ministry, at the instance of the Development Commissioners, established an Institute for Research in Agricultural Economics at Oxford, and during the years 1923 to 1926 it placed a number of advisory economists about the country. These economists, who are attached to University Departments of Agriculture and to Agricultural Colleges, each serving a group of counties, not only advise farmers in their districts, but, in many cases, have carried out important enquiries, and obtained useful and interesting economic information.

In Scotland, the Department of Agriculture contains an Economics Section, which works in close conjunction with Economics Centres at the three Agricultural Colleges. The Scottish Economics organisation was not started until 1925.

The Agricultural Economics Society plays a useful part in bringing together those interested in the subject, whether professionally engaged in it or not.

The Economics Committee of the Agricultural Research Council during the period under review discussed the general position with the late Dr. J. S. King of the Department of Agriculture for Scotland, Mr. C. S. Orwin, Director of the Oxford Institute, Dr. J. A. Venn, then Head of the Economics Branch of the Cambridge School of Agriculture, Professor A. W. Ashby of Aberystwyth, Dr. A. G. Ruston, Agricultural Economist in the University of Leeds, and Mr. J. Wyllie, Economist at the Wye Agricultural College, as well as with representatives of the Ministry of Agriculture and Fisheries.

This preliminary examination of the ground led the Committee to believe that a more detailed survey of the work going on might be postponed for a time. The broad questions of economic policy were under consideration by the Government, and were so urgent that no economic research started in 1932 could have any effect. The immediate need was to carry out Cabinet decisions, and this concerned chiefly the Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland. Thus the Agricultural Research Council decided that the survey of the Oxford Economics Institute and its allied Economic Centres might give way to the pressure of other parts of the Council's work, such, for instance, as the enquiry into research on animal diseases.

During 1934, the Economics Committee of the Agricultural Research Council is carrying out an enquiry into the work going on at the Institute for Research in Agricultural Economics at Oxford, and at other Centres at which Economic Advisers are stationed.

III. SOIL

INTRODUCTION

The Nature of Soil

Few subjects in agricultural research have made greater strides in recent years than the study of soil. The earliest view regarded soil as a mechanical mixture of particles of the underlying rock or other structure with a certain amount of dead decaying organic matter or humus. It is now realised that the clay fraction consists of complex colloidal systems in ever changing physical and chemical equilibrium, which control most of the interchanges of water and plant nutrients. The soil also is full of living and active animals and plants; worms, insects, protozoa, fungi and bacteria all contribute to its special properties. Only when the actions and interactions of all these different factors, both among themselves and with the farm crops being grown, have been studied and understood, can a fair picture be obtained of the nature of soil in its many varieties, and of its effects on the economy of the farm.

In particular, our ideas of the nature and behaviour of clay have been revolutionized. It is now regarded as a salt with colloidal properties, able to react with other salts to form new kinds of clay. Soda clays, for instance, are excessively retentive of water and sticky, but by treating them with calcium salts they can be converted into calcium clays, with the formation of a crumb structure that permits of increased fertility. The controlling factors are the ionic state of the sodium and calcium compounds, and the greater electrolytic coagulation of colloids by ions of higher valency. Thus, physics, chemistry and biology are all brought into modern research on soils.

It is not only the progress made in these sciences, and the consequent advance in methods of study, that have given soil research a prominent place in our institutions. The urgent need for investigation which those engaged in teaching found themselves faced with when, about the beginning of the century, the demand for agricultural education in this country became widespread, stimulated activity in soil investigation. To this subject, beyond questions raised by the use of fertilisers, relatively little attention had previously been given in Britain.

COMMITTEES ON ANALYTICAL METHODS

When the Agricultural Education Association surveyed the position thirty years ago, it found that, outside of Rothamsted, systematic soil studies were being made only at Wye and Reading Agricultural Colleges, and that no standard methods for soil examination were in use. A Committee was, therefore, set up with the object of devising suitable methods, and, mainly as the result of work by Hall and Luxmoore, methods for the mechanical analysis of soils were agreed upon in 1906. After the war a second Committee of the Association revised the earlier methods, in the light of the experience gained meanwhile. New methods were discussed, and were tested by the Committee at Rothamsted, at Leeds University, and at Bangor and Harper Adams Colleges. As a result, in 1926 a revised method for the mechanical analysis of soils was adopted by the Association, a method which, with slight modifications, was subsequently accepted by the International Society of Soil Science for international use.

Among the group of investigators who have developed soil studies in the post-war period there has been a very free interchange of ideas and a great deal of co-operation. In the early stages it was the Agricultural Education Association, and later the British Section of the International Society of Soil Science (which now has more than 150 members) that brought soil students together; while recently co-operative studies have been further promoted by the formation of the Imperial Bureau of Soil Science with headquarters at Rothamsted.

SOIL PHYSICS

When the Development Fund provided for the expansion of the work of Rothamsted, one of the early results was the enlargement of the Soil Physics Department. This branch of study had occupied the attention of one early investigator, Schübler; but from 1834 onwards other early workers at the science of the growing crop—Boussingault, Liebig, Lawes and Gilbert—were almost wholly concerned with the elements of plant nutrition, and the manner in which those elements reached the crop. This preoccupation with the chemical aspect of the problem lasted for at least a generation. Only two brilliant papers by Way set out the facts of base exchange in soils, facts which did not receive their full elucidation until the recent work of Gedroiz. Two men, however, Wollny in Germany and King in America, did perceive that water was a greater factor in plant production than fertilisers, and that the supply of water was determined by the physical structure of the soil as influenced to some extent at least by cultivation. They thus began a study of the Physics of the soil, and when, in 1896, Warington of Rothamsted lectured on Soil Physics at Oxford, his material came almost exclusively from foreign sources.

In 1913, Keen started work at Rothamsted, and took up the subject of water movement in soils, which had been intensively studied by Lyman Briggs and his colleagues in the United States. By his theoretical studies of the movements of water in an " ideal " soil, and his experimental studies of movements in natural soils, Keen greatly advanced our knowledge of this subject. He showed that the capillary movements of water, to which theoretical studies had attributed variable, and in some cases great, importance, must in nature be very restricted, and rarely capable of raising subsoil water more than 3 ft. to 3½ ft. above the water table.

Work on water movements was accompanied by studies of the physical properties of soil as related to the clay content, and determinations were made of such quantities as maximum water capacity, pore space, and volume expansion of dry soil when saturated.

The properties of the soil in relation to cultivating implements next attracted attention, and a study was made by Haines of the effect of the cohesion of soil particles under different moisture conditions, of the plasticity of soil and of surface friction on the power required to pull implements. A special form of dynamometer was used to measure the actual pull required under field conditions. This led to the discovery that, in the fields tested, the figures obtained were surprisingly variable, and to investigation of the causes of variation. An extension of the work on cultivating machinery led to a comparison of rotary, as contrasted with ordinary, implements; the character of the disintegrating effects of each type on the soil mass was examined, and the results of this disintegration on the subsequent tilth of the soil and on the progress of crops. These studies are still proceeding.

The Rothamsted Soil Physics Department and investigators in other countries have recently been testing what are known as " single value " methods of soil examination. Interest in soil surveys is now widespread, and the task of making mechanical analyses of the very variable material met with in the field is formidable. Rapid methods which, it is hoped, would indicate the important qualities of soil are frequently being put forward and discussed. One of these methods, the " optimum working point " of Cameron, or, to give it a more definite name, the " sticky point value ", suggested by F. Hardy, has been subjected to critical examination by Keen and others. The method consists in determining the percentage of moisture present in a thoroughly kneaded mass of soil when the mass is just sufficiently moist to stick to the fingers or knife. The figure obtained is related to the colloidal complex of the soil; and, by extracting the colloidal organic matter, a good approximation to the relative effects of organic and mineral colloids can be obtained in the case of normal calcium clay soils. For sodium clays the " sticky point " value is stated by Empire investigators to be less useful.

A second promising method for use in rapid soil examination has recently been devised at Rothamsted by Schofield and Scott Blair. It aims at ascertaining the " heaviness " of a soil in the agricultural sense; and, in normal soils, where heaviness is correlated with clay content, it indicates the amount of clay present. The method consists in ascertaining the weight which must be applied to a thin cylinder of moist soil in order to cause elongation. The test is made in a specially designed weight measuring machine. The machine (Pachimeter) can test 7-8 samples of soil per hour.

To rapid methods of soil examination Schofield has also added two for estimating lime status and base exchange capacity, subjects referred to on a later page. The second of these is characterised by E. W. Russell, who has recently made a study of a large number of rapid methods, as being of " predominant importance ".

SOIL BIOLOGY

Much interest was created by a series of studies on the effects of soil sterilisation on fertility carried out by E. J. Russell and Hutchinson at Rothamsted from 1908 to 1913, and after the war the soil's population was studied jointly by three Departments at Rothamsted. The greater part of the work of these Departments on soil organisms is biological rather than pedological in its character, but two groups of studies, which claim old associations with Rothamsted, may be mentioned here.

In the year 1887 Lawes and Gilbert were much interested in the work of Hellriegel and Wilfarth on the root nodules of *Leguminosae,* and at that time were making field observations at Rothamsted; but not until after the war was it possible there to begin systematic investigation of this subject. Thornton's studies of the nodule-organism have since enabled agriculturists to add seed-inoculation to their methods of cultivating lucerne; and it seems probable that seed-inoculation may also come into use in the growing of white clover in areas where it does not thrive naturally. Before work started at Rothamsted, the discoveries of Hellriegel and Wilfarth had been put to practical uses by growers of leguminous plants in other countries, but in this country seed-inoculation, though often resorted to, had met with no success.

A second biological subject that has long had a special interest for Rothamsted is the change which nitrogen compounds undergo in the soil. In the " eighties " Warington was studying nitrification, and had shown that nitrates in the soil resulted from the action of bacteria on organic matter. In 1890 certain bacteria were isolated and named by Winogradsky; but the organisms then described were limited in their action, and could not wholly account for changes which were known to occur in the conversion of organic nitrogen into nitrates. Recently it has been shown by Cutler that there are other organisms, quite distinct from those described by Winogradsky, which share in the formation of nitrates. While working on sugar beet effluents, in which many species of bacteria were discovered, four organisms were found capable of effecting changes hitherto unexplained, and further examination showed that these four species of bacteria were widely distributed in ordinary soils.

The soil flora appears to contain certain organisms readily adaptable to their environment, and able to effect microchemical changes if they can obtain energy from the reaction.

SOIL CHEMISTRY

General Considerations

While the Physical and Biological aspects of soil investigation have chiefly been associated with Rothamsted, in Soil Chemistry, our other institutions, too, have been active, and can claim credit for much of the progress made by British workers in the post war period.

Before the war, Hendrick of Aberdeen University had pointed out that the text-book teaching on soils, based as it was on Rothamsted studies, did not apply to the very different soil types met with on the Primary rock formations of Scotland, and that research was required before the properties which many Scottish soils were found to possess could be accounted for. Similarly, Robinson of the University College of North Wales, Bangor, when after the war he began an intensive study of the soils of North Wales, recognised that, before advisory work in that area could be fruitful, systematic research must be undertaken. Robinson's experience was more or less that of Advisory Chemists working in areas other than the south east of England. These observations led to much useful work, as for example, at Leeds University on the flocculation of the silt and clay fractions of soil, at the Edinburgh College of Agriculture on soil acidity and base exchange, at Oxford University, Harper Adams, Wye, Seale Hayne and Glasgow Colleges on soil surveys and classification, and at Bristol University on soil surveys in relation to fruit growing. Apart, however, from those coming from Rothamsted, the more important British contributions to our knowedge of soils in the post war period have come from Hendrick and Ogg and their colleagues, now grouped at the Macaulay Institute, Aberdeen; and from Bangor, where Robinson and his associates have gained for the Department of Agricultural Chemistry international recognition as a centre of soil investigation.

Although no sharp distinction can be made, broadly it would be true to say that, while the Rothamsted studies aim at relating the soil to plant growth, the Scottish and Welsh investigators have had as their main purpose the study of the soil itself; how it has been formed, how its properties have been acquired, in what degree parent material, climate, topography and man have contributed to the structure and quality of natural and cultivated soils. The Scottish workers have given special attention to parent material, and have made careful studies of the mineral fragments existing in soils and sub-soils. At Bangor much work has been done on improving the methods by which the soil's constituents can be isolated and defined. As one result of these Scottish and Welsh studies it may be claimed that we are now in a position to begin the work of classifying British soils on a satisfactory basis.

Apart from studies of the kind already noticed, which had as their object the improvement of methods of examining soils, the two subjects which have received most attention in the post-war period are soil acidity and base exchange. For a number of years studies on acidity had engaged attention at Rothamsted. The acidity of the Park grass plots and the Woburn barley plots was discussed by Hall and Miller in a paper published in 1905; and the secondary effects of fertilisers on the soil, so far as then known, were described by Hall in a paper contributed to the Journal of the R.A.S.E. just before the war. The initiative in post-war studies on acidity and base exchange may also be traced to Rothamsted; in the first case to the work of Hutchinson and MacLennan, in the second to work by Russell and Prescott on methods of determining available phosphoric acid in soils. It happened that this second piece of work, planned for another purpose, directed attention at Rothamsted to the phenomenon of absorption by soils, a subject on which much had been written, but nothing had been done in this country since the middle of last century. When, immediately after the war, the recent work on base exchange of the Russian chemist Gedroiz became known, its importance as bearing on absorption questions was at once appreciated, and base exchange problems began to be diligently studied.

Soil reaction and base exchange investigations converged to explain the land's need for lime; and the stimulus for the intensive post-war studies came from the need for a satisfactory answer to the familiar question of the soil's lime requirement. It is not difficult to account for the importance which this particular question has assumed in recent years. Liming, usually accompanied by land drainage, was the farmer's chief means of effecting land improvement throughout the greater part of the nineteenth century. When the use of artificial manures became widespread, they were, in many cases improperly, substituted for lime. Again the cost of liming rose greatly and agricultural prices fell; thus, at the time (1912), Advisory Chemists began their work in this country, a very large area of our cultivated land needed liming, and no question was more common than "What quantity of lime is required?"

To the farmer who could then look with confidence to the Adviser for an answer to a question on the quantities of artificial manures to be employed, it was unsatisfactory to find that, on the use of the expensive material lime, he could get little useful guidance. To the Adviser the position was even more unsatisfactory, for when he did venture an answer he knew that his figure was largely a guess. It was for these reasons that the various uses of lime have been so closely studied in recent years, and though much experimental work in the field is still required before advice on liming can be given with confidence, it may be claimed that good progress has been made since the war, and that, in some parts of the country, though not in all, the Advisory Chemist is now able to give definite guidance on the need of different soils for lime.

Soil Reaction

Returning to the development of these soil reaction and base exchange studies, we find that the method of ascertaining lime requirement devised by Hutchinson and MacLennan in 1913 was given an extensive trial in different parts of Britain. In some districts the method was found to be most useful; in others, however, it failed altogether to show what quantity of lime was required by the soil. A similar experience was met with when other methods of testing for lime requirement were employed. And it was soon recognised that further advance depended on a clearer understanding of the precise effect which lime had on soils and crops.

Beginning with studies by E. A. Fisher immediately after the war, the subject of the soil's reaction has been very fully investigated at Rothamsted. Methods of estimating the intensity of soil acidity (i.e., the hydrogen-ion concentration or pH value) have been examined, and E. M. Crowther has subjected to critical study, and perfected, an electrometric method of determining pH values now generally used in laboratories. Crowther has tested this method on soils of known history from Rothamsted and Woburn experimental plots and on other selected soils, and has pointed out the precautions necessary in making the test and in drawing inferences. This was a very necessary contribution to soil science, since for a time, soil workers had been too freely adopting this convenient, but conventional, laboratory method, and there was a tendency to place undue weight on the indications of pH value obtained. The pH value has undoubtedly been shown to be a very useful figure when comparing the lime status of soils of similar origin, and the requirement of crops growing in similar climates; but it does not follow that a series of pH values compiled to show the relative tolerance of crops to acidity in (e.g.) the English Midlands would hold good for soils in N.E. Scotland.

Base Exchange

The property which soils have of exchanging one base for another was remarked by English chemists nearly a century ago in connection with the absorption of ammonia by soil. It had an obvious bearing on the practice of manuring, and so aroused great interest; later the power of soils to retain useful bases was suggested as a means of gauging fertility. But the property, though much canvassed, was not understood, and even now different views are held on the relative importance of physical and chemical action in explaining base exchange phenomena. The general view is that the exchange is due to chemical action, taking place at the surface only of the soil colloids. The rate at which bases are exchanged points to a purely surface action. The amount of the exchange in the case of four bases (lime, magnesia, potash and soda) has been determined in many soils, and it has been found that in normal soils about 80 per cent. of the total exchange is accounted for by lime; thus, in studying the amount of base exchange, it frequently suffices to measure the exchangeable calcium. The total quantity of exchangeable base varies widely, not only with the percentage of colloidal matter present, but with the degree to which soils have been subjected to leaching. Soils well supplied with calcium carbonate usually, but not aways, contain the maximum amount of exchangeable bases which the colloids can hold, and are said to be saturated; as the percentage of calcium carbonate falls, soils become unsaturated, hydrogen replaces calcium, and the soil's reaction as measured by its pH value becomes increasingly acid. A low figure for exchangeable calcium thus furnishes a second indication that liming is required. In examining a district in which the lime status of soils is unknown, determinations of both the pH value and of the exchangeable calcium are usually resorted to.

In the Bangor laboratory, Rice Williams has made a series of studies of methods of estimating base exchange. It was found that, in the case of certain carbonate-free soils of N. Wales, the two standard methods of estimating exchangeable calcium (those of Hissink and Gedroiz) did not give the same results, and a new method was devised which, with a modification, necessary in the case of heavy clay soils, has proved to be satisfactory. In the case of soils containing free calcium carbonate, Hissink's method is apt to overstate the amount of exhangeable calcium present. E. M. Crowther and others have suggested means of avoiding this error, and recently Rice Williams has devised a new method, founded, like his method for carbonate-free soils, on the use of acetic acid as a solvent.

Base exchanges being associated mainly, though not entirely, with the soil's colloidal complex, the respective shares of clay particles and organic matter in the exchanges have engaged the attention of several soil investigators. To this subject Rice Williams has made important contributions. Determinations of the total quantities of exchangeable bases in a number of Welsh soils, and in certain representative soils from other countries, showed that, when these soils were fully saturated with lime, the percentage of exchangeable bases associated respectively with clay and organic matter could be ascertained by formula. Organic colloids contribute approximately eight times the quantity of bases contributed to exchanges by clay colloids; or taking, as is preferable, only oxidisable organic matter into account, the relationship becomes 10.5:1. Since, however, the percentage of clay in ordinary soils greatly exceeds that of organic matter, the clay complex is by far the most important source of exchangeable bases.

Advances in the theories of soil reaction and base exchange in the past ten years have been put to practical use by our soil students in a number of cases. Thus at Rothamsted they have thrown new light on the changes occurring in the classical plots of Broadbalk and the Park. The changes during a 50 year cycle in the soils of the Woburn plots have been traced, and incidentally a point of great interest to agriculturists has been established. Superphosphate, the most widely used of all artificial manures, was long suspected of increasing soil acidity; the history of the Woburn plots proves the suspicion to be unfounded. Long continued applications of superphosphate to this soil, naturally deficient in lime, have not reduced the quantity of exchangeable bases. At Rothamsted, again, base exchange theory provided Page with an explanation of the very serious damage which clay soils suffer when flooded by sea water.

In Scotland, Hendrick, Ogg and others at the Aberdeen and Edinburgh Colleges of Agriculture have studied base exchange and have carried out surveys of soil acidity, employing hydrogen-ion concentration, base exchange, and lime requirement tests in connection with advisory work among farmers. In both Scotland and Wales similar studies have also been made in connection with soil classification with the object of gaining information about pedogenic processes.

From the agricultural point of view, lime is by far the most important exchangeable base in British soils; only in the case of arid, or of irrigated, soils does soda claim greater importance. It is usual when investigating base exchange phenomena to determine lime, magnesia, potash and soda, but records of other bases are rare. A. W. Smith (Edinburgh College) found weighable quantities of iron and alumina in three out of twenty Scottish soils examined by him, and Hendrick found these, and also a trace of manganese, in the Craibstone soil. The fact that one of the most widely used and valued qualitative tests for sourness in soil—that devised by Comber of Leeds—depends on the replacement of iron by a potassium salt, would seem to show that iron in an exchangeable form must frequently occur in soils.

The Soil's Clay Fraction and Soil Formation

The composition of the soil's clay fraction which has been much studied in connection with base exchange phenomena, has also been examined because of the information it supplies on the soil's formation. The relative proportions of silica to alumina, and of silica to alumina and ferric oxide in the different soil horizons, depend not only on the parent material, but upon the degree of weathering. In ancient soils the latter may have much the more important influence, so that climate has been adopted in many countries as the chief factor in classifying soils. In the cool humid climates of Northern Europe, when the silicates of the parent material are weathered, alumina and ferric oxide are carried down from the upper to the lower soil horizons; thus, while in the upper layer the molecular SiO_2/Al_2O_3 ratio may be 3:1, in the lower, ratios of 2:1 might be expected. In arid countries ratios of 5 or 6:1 may be found, and in the humid tropics ratios of less than 2:1 are common. The ratio is further of importance since, in any particular area, it is found that, as it rises, the special characteristics of clay soil become more pronounced. In this country Robinson has used the silica/sesquioxide ratio of the clay fraction in studying the soils of N. Wales, and comparison of the ratios found in the upper and underlying soil horizons, which usually vary between the limits 3:1 and 2:1 has led him to modify his former view that certain of these Welsh soils belong to the class known as "immature." He now finds that the special characters are the result of erosion, and that they have close affinities with certain well known Continental groups.

E. M. Crowther has used the silica/alumina ratio of the soil's clay fraction in a very interesting study of the influence of parent material, rainfall and temperature on 30 typical American soils. Where climates are similar, highly siliceous clays were found in young soils derived from parent material repeatedly re-worked by water, while the lowest ratios were found in sedentary soils resulting from the weathering of igneous rocks. He points out that a high ratio may arise in one of two ways:—as above from re-working by water (this explains the high ratios found by Hall and Russell in some of the clays of S.E. England) or by the weathering of alkaline soils in arid regions in the presence of soluble silicates, as e.g., in the Sudan. Where climates differ, a high rainfall tends to alter ratios because of leaching; and rises in temperature, by reducing drainage, counteract rainfall effects. Thus, in the case investigated, it was found that for each rise in mean temperature of 1° F. rainfall must increase by 0.88 ins. to give a constant silica/alumina ratio in soil. The fact that in the United States rainfall and temperature rise and fall together masked the effects of climate on soil, which had been noted in Russia, where temperature falls, but rainfall rises from south to north. Thus the climatic zones recognised by Russian pedologists do not hold for the United States. The very simple explanation revealed by Crowther's statistical analysis had escaped notice, and his paper records the amusing fact that when, on an excursion of the International Society of Soil Science in the United States, a distinguished Russian pedologist first saw a prairie soil, he refused to believe the figure given him for local rainfall, on the ground that the soil profile in front of him could not possibly be accounted for by it.

Mineralogical Analysis of Soils

In Scotland, as in Wales, many soils now classed as immature may subsequently be shown to owe their present character to the erosion of an upper layer; but it is likely that immature soils largely predominate. These immature soils are directly derived from the drift covering the rock formations in most parts of Scotland, but the association of soil with rock is close, for the matrix of the drift is usually of local origin. Where the rock is igneous, the drift is generally thin, and even when, as in the case of Old Red Sandstone soils, they may rest on thick layers of boulder clay, examination of the minerals in soil and drift supplies evidence of the rock's influence on the soil. While it would be wholly misleading to describe as powdered rock such soils as are found in southern England, this description would not be far from true if applied to soils common enough in northern Scotland. Hendrick and Ogg emphasized differences in the soils of the two countries, when 20 years ago their partnership in soil investigation began in Aberdeen, and their original studies have influenced most of the work that has since been done in Scotland. In the northern country, soil acidity and base exchange capacity are being closely studied, in the Highlands and Islands the special problems of peaty soils are now being taken up, and in the south west soil texture, in relation to classification, has received more attention than elsewhere. In one type of soil investigation—mineralogical analysis—Scottish workers can claim a monopoly, at least in so far as British studies are concerned.

The obvious dependence of the qualities of certain soils on the underlying rock, the fact that minerals of the same kind could be found in both, and the further fact that many of these minerals were known to contain plant food materials—materials which, if not immediately available, were at least in reserve—led Hendrick and Newlands to devise methods for the separation of the soil minerals into groups. The methods were used by the authors to compare certain typical soils of the north east of Scotland with the soils of Rothamsted and Woburn, and subsequently by Hart to compare representative soils in the south east of Scotland with those examined by Hendrick and Newlands. Striking differences were discovered, bearing not only on the soil's origin but on its fertility also. The results cannot be discussed here, but even from the small number of soils (60-70) hitherto reported on, it may be inferred that, whereas in England and Wales study of the soil's "clay fraction" provides information of the kind most useful to the farmer, in the case of northern Scottish soils, where the "clay fraction" is always small, the nature and conditions of the minerals present in the "fine sand fraction" call for further study by those who endeavour to assess the soil's agricultural quality.

Organic Matter of Soils

The Chemistry of the soil's organic matter has been continuously studied at Rothamsted and Bangor in recent years; at the former by Page and his assistants, at the latter by Robinson and McLean. The problem taken up by Page was the origin of humus, an old and difficult question not yet finally answered. In the case of ordinary soils, Page's hypothesis is that humus is derived from plant lignin, which in the presence of nitrogenous matter forms a complex material in which carbon and nitrogen exist in stable combination. An alternative hypothesis, formerly the usual one, is that soil has the power of converting all kinds of vegetable and animal organic matter into humus.

The main evidence in support of the lignin theory put forward by Page is interesting, as showing the great value to investigators of access to soils of known history. Studies made of the organic matter present in 3 plots of Broadbalk Field (wheat since 1843) and 3 in Barnfield (swedes 1856-75, mangolds since 1876) showed that in all these plots, differently manured and cropped for many years, the organic matter was similar in character. Concentrating attention on Plot 2, Broadbalk (farmyard manure) where the organic residues were derived from straw, and Plot 8A Barnfield (ammonium salts) where the organic residues were derived from swede and mangold leaves, it was shown that the humus present in the soils was practically identical in its character. Rothamsted has also shared in the many attempts made to synthesize humus, and has compared the humic acids derived from natural products with those made artificially. Some of these humic acids prepared artificially did not show true acid properties, while others did. All the preparations from natural humus had acid properties.

At Bangor, attention to soil humus was first drawn by Robinson who, in working on the improvement of analytical methods, suggested the use of hydrogen peroxide in the preliminary treatment of humus soils for mechanical analysis. Later, with a colleague, he suggested that hydrogen peroxide might be employed to differentiate true humus from undecomposed organic remains. An American namesake, using stronger solutions than Robinson had employed, criticised the method, and pointed out that hydrogen peroxide attacked also non-humified organic matter. This led McLean of Bangor to re-investigate the subject, and, while he found that in fact a 6 per cent. solution of hydrogen peroxide did not accurately separate humified from raw organic matter, this reagent had valuable uses for the soil investigator. By its use, the organic matter of the soil could be separated into material of three types (1) organic matter oxidised by 3 per cent. hydrogen peroxide, having the general character of humus with a C : N ratio of about 10 : 1, (2) a residue almost completely oxidised by 6 per cent. hydrogen peroxide, consisting of organic matter entirely free from nitrogen, (3) a further residue containing nitrogen unaffected by 6 per cent. hydrogen peroxide.

By applying this method of fractionating organic matter to 26 soils (about one-third of them Welsh, the remainder including English and typical foreign soils) McLean has recently made a notable contribution to the study of soil organic matter. He regards the organic matter of all soils as composed of the fractions indicated above. The first is an oxidisable complex specific to the soil, has a definite composition, and accounts for 70-80 per cent. of the total carbon and nitrogen. The second accounts for 10-15 per cent. of the soil's carbon. The third accounts for about 5 per cent. of the soil's carbon and the balance of the nitrogen not oxidised by 3 per cent. hydrogen peroxide. Agreeing with Page that lignin is probably the chief contributor to the non-nitrogenous humus complex, and accepting the general view that the nitrogen of humus results from the synthesis of nitrogenous substance by micro-organisms, McLean agrees that there is as yet " no experimental evidence to prove that these two substances exist in the soil as definite components of organic matter ". McLean, however, opposes the view of Waksman, a leading American authority on soil organic matter who regards lignin humus and protein as independent complexes, and believes that the oxidisable complex, as defined above, contains nitrogen in definite combination with carbon derived from lignin. The tenacity with which Page finds humic acid to retain its nitrogen supports McLean's view.

The fresh organic matter of the soil, like humus, is of great importance to the practical farmer. The rate at which it disappears, and the frequency with which it must be restored by dunging or green manuring, govern some of the most familiar farm processes. The fate of fresh organic matter in soil and the causes which lead to its loss are now being investigated by E. M. Crowther and his colleagues at Rothamsted.

SOIL SURVEYS AND SOIL MAPPING

Much of the work referred to above has been undertaken in connection with Soil Surveying and Mapping. The only maps generally available at the present time for those interested in soil distribution are the maps of the Geological Survey, and although they are very helpful and are in constant use by soil students, they fail to give the full information required by those engaged in educational work among farmers. Hence a number of Advisers prepared manuscript maps for their own use. It was obviously desirable that these local maps should not only be comparable, but should contain the greatest possible amount of useful information, and this led to consideration of the method of classification which should be followed in British soil maps. Agreement on the best method was not easily reached, so that until recently the main energies of soil surveyors were concentrated on testing out in the field the different methods suggested. For the surface soil, classification by texture was useful, but even when precision was given to the definition of sands, loams, etc., it was found that to many districts the method was ill suited, and attention was given to the mode of formation of the whole soil mass as it occurs in the field. This involved consideration of the relative effects of rock material, climate and vegetation.

That a marked relationship existed between soils and rock formations was noted as soon as geologists began to map British strata (William Smith, Father of English geology, was himself a land surveyor) and much information on the subject was collected early in the nineteenth century, so that Johnston in his " Lectures " published in 1840 was able to give a good general account of British soils classified on a geological basis. Later writers added local notes, but, until the beginning of the present century, little additional work was done on the subject. A demand for further information then arose, and soil surveys were undertaken in a number of areas. These surveys were, however, planned for various purposes, and the methods adopted depended on the point of view of the investigator; thus some were essentially chemical, others were ecological, others again were economic, and little information on the characteristics of the soil itself as it occurs in nature was obtained from most of them. From the point of view of the soil investigator, the most valuable of these surveys was that of Hall and Russell on "The Agriculture and Soils of Kent, Surrey and Sussex" (1911). In those counties the conditions were favourable to the method adopted. The area itself was varied, eighteen geological formations were represented; and, as there was little drift, soil boundaries conformed closely to those of the geological map; thus it was possible to establish clear relationships between the agricultural features, the chemical and mechanical composition of soils, and the geological structure.

The success of other investigators adopting the same methods varied, and in some cases, as in the eastern counties, much time and money were expended with little advantage. In other districts, however, substantial progress was made as a result of these preliminary attempts to map soils. The association of Stapledon with O. T. Jones in a survey of the Aberystwyth area, laid the foundation for the pasture improvement work now in progress in Wales. Again in N. Wales, G. W. Robinson, who, in beginning work in his area, had planned his methods on the experience gained by Hall and Russell, soon discovered essential differences between the soils overlying palaeozoic rocks and those of the south eastern counties, and he initiated his detailed pedological studies which have contributed so much to the progress of soil science in this country. Influenced by Robinson, Morley Davies took up the systematic study of soil distribution at Harper Adams College, with the result that many thousands of acres in the West Midlands have now been surveyed and mapped. In this period too, Ogg who, with Hendrick, had begun the study of soil distribution before the war, was engaged in pioneer surveys in the Edinburgh district.

By 1924 the time had come for establishing closer contact with the Geological Survey. Our soil students, whose training had mainly been in the chemical laboratory, had served an apprenticeship in the field; they knew the complexity of their problems, and realised that in methods of surveying and mapping they had much to learn from the experienced officers of the Geological Survey. A conference was therefore arranged where there was an exchange of views. This conference resulted in the setting up of a joint organisation for promoting the study of soil surveying. Meetings were held for the purpose of settling a basis of classification and the nature of the methods and symbols to be employed in mapping soils; while from time to time Field Meetings were held where geologists and agriculturists together tested methods agreed in the committee room.

The assistance of the Geological Survey, freely given and greatly appreciated by soil surveyors, led to a rapid advance, and to additions to the number of local surveyors. In order to secure uniformity in the work of classifying and mapping, a Soils Correlation Committee was set up by the Departments of Agriculture to visit and examine selected soils in each district in which surveying was in progress. This Committee, on which both geology and agriculture are represented, has so far identified and described about 150 soil series in England and Wales, and about 80 in Scotland. It has also drawn up a list of the types of parent material contributing to British soils.

Each " soil series " recognised by the Committee includes within it all those soils which are essentially similar in respect of parent material, mode of formation, topographical position and drainage conditions. The soil series are further subdivided into classes depending on the texture. All the conditions responsible for a soil series are reflected in the soil's profile, or section, and the profile is studied either in natural sections, or by boring with an augur. The profile is, therefore, the unit to which the surveyor's attention is now mainly directed in the field.

It will be evident from this statement that, as compared with other natural objects, the classification of soils raises difficult questions. The unit plant or animal presents definite characters which systematists can use, the rock formation has petrological, or palæontological, features which serve to identify it with certainty; but the soil profile presents features which may vary widely, and often by very gradual stages, within a single field, and when samples are taken for further study, laboratory examination may destroy some of those characters which would assist in identification.

The system of classification on profile character was not adopted, therefore, until after the whole subject had been fully discussed; and, before agreeing to classify soils on the characters shown by their profiles, the Committee responsible had not only the experience gained in other countries to guide them, but had had the assistance of expert American and Russian surveyors in examining British soils.

Much difference of opinion existed, and indeed still exists, on the relative merits of methods of classification, and while there has now been agreement to adopt in Britain a modified form of a method originating in Russia and elaborated in the United States, it should be recognised that a great deal of work will be required before British soils can be classed and mapped in a way that will satisfy those engaged in the task. It seems likely that when this task has been completed at least 200 well-defined soil series, and many more soil classes will be found to occur in Great Britain. The number may not, perhaps, surprise the farmer, who although contented to describe his soils as clays, loams, sands and chalks, knows from experience how widely the characters of these groups vary from district to district; nor should it surprise the botanist who has marked the range of soil conditions which plant associations indicate; but, although knowledge that our soils present a great variety may not be new, the systematic classification of the types represented in Britain has not been carried out before, and will be of substantial value to farmers and their scientific advisers.

From the scientific aspect too the study of British soils should prove of much interest. The work so far done has shown that broad climatic groupings, useful as they are in explaining the general distribution of the soils of continents, have a limited application to the soils of Britain. It is not only because our climate is relatively equable that soil students in this country place more emphasis on geology than the Russians and Americans, who have been their teachers. There was at first a tendency here, as recently has been the case in Europe, to regard climate as the all important factor; but field studies point to the conclusion that geological history has played a greater part in moulding the soils of Britain than it has in the case of the continental areas where climatic grouping has proved so useful.

Early in the nineteenth century it was recognised that the variety of our soils might be explained by the extensive range of geological formations represented in Great Britain; but this is not only because of the original quality of the material present in rocks. We have since learned to appreciate the great influence of climate on soil formation; but, as contrasted with other countries where the subject has been studied, it has been found that a relatively large proportion of our soils owe their present features not to recent climate, but to the climates of geological times; since modern soils are frequently derived from rocks which were themselves in part the product of ancient soils, the results of the weathering and leaching processes undergone by earlier rock formations. Thus, in accounting for the properties of many Scottish soils, it is the climate of the Ice Age that appears to have been chiefly responsible, while over a broad band of southern England some of the essential characters of the soils now in cultivation were stamped on them by the climate of the Jurassic period. This does not mean that the recent climate, with its consequent effects on vegetation, is not of importance here. There is much evidence in this country of the rapidity with which climate can alter our soils. Even in the drier districts it can be shown, for example, that well marked podsols may develop in two centuries or less. It does mean, however, that in Britain the student of soil formation has a very complex problem to unravel, and that, while working alongside of the geologist, he concentrates attention on the soil's profile, he must frequently reverse the geologist's motto and seek the key to the present in the past.

INSTITUTES FOR SOIL RESEARCH

Rothamsted Experimental Station

The oldest Agricultural Research Station in the world is Sir John Lawes' foundation at Rothamsted, Harpenden, now under the direction of Sir John Russell. The original experiments were concerned with the effects of manuring the soil on the growth of farm plants, especially cereals, and led to the establishment by Lawes of the manufacture of chemical manures. The more important of the original series of experiments are still carried on from year to year, as, for example, on wheat in the field called Broadbalk, and on meadow hay in the Park.

The endowment of the Station began with the Lawes Trust of £100,000. New buildings and equipment have been provided at a cost of about £75,000. The income of the Lawes Trust is now supplemented from other sources, including grants from the Development Fund amounting to £26,210 in the academic year 1931-32 and to £26,380 in the year 1932-33.

Rothamsted is the chief home in this country of research on soil, and its influence on the plant in health and disease. The Plants and Soils Committees of the Agricultural Research Council visited Rothamsted in May, 1933. They then carried out a general inspection of the work going on, but left a more detailed study to Sub-Committees. These Sub-Committees visited the Station during 1934, with results which will appear in the next Annual Report.

At the time of the preliminary visit, the Botany Department was studying the effects of competition between plants in the field, including the composition of grass herbage. The final state of a grass field is largely independent of the seeds used to sow it down. It depends much more on the climate, the nature of the soil, on the physical and chemical after treatment, and on the closeness of the grazing.

In the Chemical Department under the direction of Dr. E. M. Crowther, studies were being made of the effects on crops of various forms of nutrients, including the newer forms of artificial fertilizers. Chemistry could not yet give a complete account of a crop; for instance, chemical methods of evaluating barley gave consistent grading, but the maltsters' buyers did not always agree with the chemical conclusions. By arrangement with the Institute of Brewing, brewing and malting tests of barleys were being carried out. It was found that simple relations existed between the amounts of individual proteins and the total protein contents, irrespective of the conditions in which the crop was grown. A formula is thus suggested by which the quantity of extract can be determined from the chemical analysis of the barley.

The effect on soil of crop residues and other organic matter is various. On the light soil at Woburn, for instance, it had long ago been found that poor results followed the use of tares as green manure and better ones with mustard, the opposite being the case on the Rothamsted soil. After tares, nitrification was rapid at Woburn, and nitrates were leached out of the soil before they could be used by the following cereal crop. The effects of manuring on sugar beet was being studied at 14 different centres.

In the Physical Department, Dr. B. A. Keen and his staff have recently been investigating the effects of different types of rotary cultivation. A scheme of experiment has been laid out which will compare the effects of rotary cultivation with ploughing (inversion) or simple stirring by cultivators. One immediate effect of rotary cultivation is an increase of certain classes of weeds, the rhizomes or the roots of which are cut up and distributed through the soil by the revolving tines. Only a long period experiment can determine the resultant effect of these varied methods of working the soil.

The physical staff were also investigating the crumb formation in clay when different amounts of liquid were added, by methods which had been found applicable to problems arising in connection with subjects other than agriculture. Apparatus has been designed for measuring the plastic and other physical properties of clay, and, since clay is in some respects an imperfect material for determining some of the relationships between colloid structure and physical properties like plasticity and elasticity, some of the work for the last year or more has been turned on to the study of dough. The conlusions arrived at with regard to dough can, it is held, then be applied to clay.

In the Micro-biology Department, Mr. D. W. Cutler and his colleagues were examining the organisms in the soil, particularly the bacteria concerned with the transformation of the nitrogen compounds in soil and water.

As an outcome of this work, at the request of the Department of Scientific and Industrial Research, the staff had been studying for seven years the methods of purifying the effluents from sugar-beet factories, and, with the help of the Fermentation Department, had worked out a system of settlement, filtration and oxidation, which gave 95 per cent. purification. They were now turning their attention to the washings from milk depots. If the washings were poured direct on to filters, the filters became clogged; it was necessary to give the washings preliminary treatment in a septic tank. They were isolating the organisms from these septic tanks.

The Fermentation Department, under Mr. E. H. Richards, was also concerned with the decomposition of organic matter as manure, and the availability of the different compounds of nitrogen as the season progresses. Soil organisms seemed to make more use of ammonia early in the season and of nitrates later.

In the Bacteriological Department, Dr. H. G. Thornton was continuing his successful work on the inoculation of lucerne, partly financed by a grant from the Royal Agricultural Society of England, by extended studies on the nitrogen fixation of lucerne and other legumes. Infection of the nodules by bacteria takes place through the root hairs, and is preceded by deformation of those hairs. This process is stopped by a dose of sodium nitrate; at the same time in the presence of nitrate the bacteria in the nodules change their function, cease to fix nitrogen and become parasitic on the leguminous host. Similar effects occur in the absence of boron, a trace of which the plant obtains from most soils, and in plants grown in the dark.

Mr. H. Nicol had isolated an organism which produced a sticky mucilage, and, when associated with cellulose-splitting fungi, was probably responsible for " stickiness " in farmyard manure, and in Adco, the material which was developed at Rothamsted some years ago for converting vegetable refuse into manure.

In the Insecticide and Fungicide Department, Dr. F. Tattersfield, in conjunction with Mr. J. C. F. Fryer of the Ministry of Agriculture and Fisheries, was studying the toxic substances contained in various vegetable insecticides, particularly pyrethrum and derris root. Dr. Tattersfield isolated and determined the composition of the toxins, and from that had proceeded to methods of evaluating their content in the natural materials. By this means the insecticidal value of these materials can now be accurately determined, and a basis is provided both for their purchase by the manufacturer and for the standardisation of the preparation sold to the fruit grower.

The study of Virus, going on in the Plant Pathology Department, is described under the heading of Diseases of Plants, see p. 68.

The work of the members of the Entomological Department under Dr. C. B. Williams consisted of (1) general investigations and (2) bee researches. In the former they studied the causes of the variations in the numbers of insect populations, which might depend on climatic changes or parasitism. To this end they were examining such insects as the midges on Broadbalk field, and the midges of grass and of willow trees.

Mr. D. M. T. Morland was studying the duties of bees of different ages, and, confirming work in Germany, found that the young bees first took care of the brood, then of the younger and next of the older larvae, and finally went foraging. He was also correlating sunshine and activity.

The Statistical Department, in effect the creation of Dr. R. A. Fisher, now Galton Professor of Eugenics and Applied Statistics at University College, London, is under the direction of Mr. F. Yates. The department has lately been concerned with a new method of field experimentation, first devised six or seven years ago. The main features are (1) "replication," i.e., the repetition of similar plots, (2) an estimate of the probable error, made valid by random distribution of the plots, and (3) control of local experiments by laying out small plots in Latin squares and blocks, so as to diminish the effect of differences in soil fertility.* The Statistical Department is responsible both for designing all experiments at Rothamsted and for analysing the results. It also acts as an informal Statistical Bureau for the Empire.

The results of a detailed examination by Sub-Committees of the Agricultural Research Council of the work going on at Rothamsted will be summarised in the next Annual Report.

Macaulay Institute

The Macaulay Institute for Soil Research at Aberdeen was founded in 1930 by Mr. T. B. Macaulay, who provided £27,000 for buildings and equipment and a contribution to the cost of upkeep, towards which the Development Fund contributed about £4,600 in 1932-33. Dr. W. G. Ogg is the Director.

The Institute was not inspected in the period covered by this Report. A Sub-Committee visited it during 1934, and detailed reference to its work is deferred until the report of the Sub-Committee has been considered by the Council.

It may here be mentioned, however, that studies of sedentary and drift soils and their profiles on cultivated and uncultivated ground have been carried on for some years, and determinations made of the mineralogical composition of soils in connection with their geology. Much work relating to soil classification is in hand, but for the present surveying and mapping are being restricted to areas presenting features of special interest or to localities close at hand because of the travelling costs involved in distant work.

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* For an account of the theory of these methods, see p. 177.

The effect of lime deficiency on soils and on the malnutrition of sheep is being examined in conjunction with the Animal Diseases Research Association. Pot culture work on soils is done jointly with the North of Scotland College of Agriculture. Drain gauges have been used to investigate the losses of nitrogen in intensive manuring of closely cut grass land. The reclamation of moorland is studied on a farm in the Island of Lewis, where successful results have been secured in establishing pastures.

IV. PLANTS

INTRODUCTION

Until the end of the last century, the only method of obtaining new varieties of plants was by the selection as parents of individuals which showed an approach to the qualities desired. But the re-discovery in 1900 of the forgotten work of Mendel gave to breeders a more scientific and more powerful method.

Mendel proved that certain qualities in plants are inherited as indivisible units, and could be introduced into new individuals at will. It is now known that two or more different units are often linked together, and sometimes units can be added in successive doses; but these complications, while they increase the difficulties of the breeder, do not affect the scientific importance of Mendelian principles. Again, Mendel's units have been correlated with minute structures, now called genes, in the reproductive cells, and thus realistic significance has been given to them.

Research on the plant with an economic end in view aims at the increase of production, on the one hand by the improvement of the plant itself in its innate capacity for growth, and on the other by a better knowledge of environmental conditions to put the plant in a position to exercise that capacity to the full.

Taking the plant itself as starting point, the improvements effected in many respects are already enormous. Everyone is familiar with the facts that " Marquis " wheat, a creation of Saunders, has by its early ripening habit pushed the wheat belt north and added many millions of acres to the farm lands of Canada, and again that the disease resistant sugar-canes known as P.O.J., bred in Java, have raised its output of sugar to an average of 15 tons per hectare as compared with a world's average of less than 4, and an average of 7.5 tons in Hawaii, the country with the next highest yield.

It would be easy to sum up the financial gains that accrue to the farmer from even a five per cent. increase in the average yield of a particular crop, had not such arguments become generally discredited by the supposed over production of food in the world. Leaving however this large economic aspect (in which is involved the question of the utility of research at all), it still is evident that the possibilities of the genetic improvement of crops are not unlimited. Many of the older cultivated plants of the temperate zone, through the long continued work of plant breeders and selectors, even on the empiric basis, would appear to be near that maximum of production of raw material from the fundamental elements of air, water and soil that can be associated with the general make-up of the plant. The wheats and barleys of Western Europe seem to have reached this point from the researches of Sir Rowland Biffen and the Plant Breeding Institute at Cambridge; so does sugar beet, and, according to the experience of the East Malling investigators, even a fruit like the black currant has possibly been developed up to its maximum of gross production. Only some happy accident, resulting in a revolution in the inner constitution of such plants, will give them a new starting point on a higher level. On the other hand, tropical and semi-tropical plants are less advanced, and offer greater possibilities of immediate improvement. But even within these limits much remains to be done. A shift may be effected in the proportion of the raw material that is transformed into the product useful to man; in a cereal, for example, the grain may be increased at the expense of the straw. Plants may be bred to suit changed environments; two wheats may be equally good in conditions of moderate fertility, but one may be much more responsive than the other to high manuring, either because of a stiffer straw capable of holding up the heavier crop against lodging, or because of disease resistance. The Aberystwyth station is working for a quick ripening oat, because the ordinary heavy yielding oats cannot mature on the wet Welsh uplands.

Quality in our agricultural products is again very much a matter of breeding. In wheat, high protein content and " strength " from the milling and baking point of view is to a large extent a product of environment, to be found, for example, in the wheats grown in Hungary and the Danubian plain, and again in the similar steppe climates of Manitoba and the Middle West. But, in the early testing of foreign varieties in this country, one wheat, " Red Fife ", coming from Canada, though of Galician origin, retained its strength to a considerable degree, though this did not happen with the other varieties in which the quality was environmental only. Sir Rowland Biffen thus obtained a starting point for the creation of his " Yeoman " varieties, which combine strength approximating to that of the hard Canadian wheats with the cropping power of English varieties on good soil. Milled alone, " Yeoman " will produce flour equal to that from the usual mixture of hard and soft wheats employed by millers; used in mixture, it can diminish the millers dependence upon the more expensive strong wheats.

By a strange irony, while the efforts of the Cambridge Institute were thus directed to produce a strong milling wheat, it became apparent that the greater demand in this country was for wheat displaying the " English " characteristics to the highest degree, i.e., a soft white wheat for biscuit flour or, in the lower grades, for poultry feeding, thus calling for a corresponding change in the breeding programme.

The modernisation of agriculture indeed makes particular demands upon plant breeders to supply the industry with fruits and vegetables capable of standardisation and suitable to processing. For example, fruits for canning and drying should have a higher proportion of fibre than is desirable if the fruit is to be eaten fresh; indeed it is to be feared that commercial considerations often tend to rule out the finest qualities of fruit. The best cherries are unlikely ever to reach the market because of their tender flesh; the strawberry that is desired by the market grower, and towards which the breeder is encouraged to work, is one that will colour brilliantly before it is ripe, when the flesh is still so firm that the berry will bounce when dropped.

Among the " qualities " of most importance to the fruit grower and horticulturist are sterility and fertility, which, while in part influenced by environment, are in the first instance determined by genetic constitution. Much has been done to ascertain the relationships between varieties of apples, cherries, plums and pears that will ensure fertilisation. Some varieties are self sterile, all are more fertile with the pollen of a different variety, though among the cherries and plums in particular there are cross incompatabilities that the intending planter should know. These relations are governed by the structure of the cell nucleus, and to some extent have become predictable; for instance, it is possible to direct the breeding of plums so as to ensure self fertility, a desirable if not essential quality in commercial plantations. The way in which the structure of the nucleus throws light on so many of the problems of the fruit grower, and provides both guidance and warning to the breeder, is one of the most interesting developments of recent science. The elucidation of nucleus structure demanded long and exhaustive work in the field of pure science, before there could be any suspicion that it might have applications in practice.

Many fruits are best grown by grafting a " scion " of the fruit tree on to a " stock " of an allied species or variety. The relationship of stock to scion may be regarded either as a matter of the plant itself or an environmental effect. In either case it is a matter of extreme importance in practical fruit growing, because it is only by using suitable stocks that the grower can secure uniformity in his plantations, uniformity that extends to habit of growth, early or late maturity, methods of pruning and spraying and many other features of management. It was the work of the East Malling Station that cleared up the confusion existing among the vegetatively reproduced stocks of apples; the Long Ashton Station has dealt chiefly with the seedling stocks.

There is much yet to learn about the relationship between stock and scion, how far the stock effect is due to the root system or to the stem, and what effect in turn the scion has upon the stock. In this connection we see the advantages that may arise when a problem is approached independently by two sets of workers, as at East Malling and Long Ashton. It might be ruled administratively that there had been overlapping; in fact each station contributes its own point of view, and the mutual criticisms stimulate fresh work until some reasonable agreement is reached. In this case the issues are of practical importance, for the stock on any consideration is the medium through which the productive scion receives its nutriment, and the evidence shows that it is not merely a neutral filter.

Even as regards the choice of the best apple stocks, finality has by no means been reached, and with plums, pears and peaches much work remains to be done.

Returning to the more general question, breeding for disease resistance is one of the most promising lines of work. The discovery some twenty-five years ago of a potato variety, growing vigorously on an allotment so contaminated with " wart disease " that the other varieties there collapsed, has led to the production of a range of potatoes, all immune to this disease. These immune varieties have almost wholly displaced the susceptible varieties, only one or two of which still remain in cultivation because of some special quality that has not yet been combined with immunity in the new race.

Immunity from insect attacks and from fungal disease may also be obtained. Starting from the known resistance of one variety of apple, "Northern Spy," to woolly aphis, crosses were made at the John Innes Horticultural Institution between it and the varieties employed as stocks because of the readiness with which they will root as layers. The resulting seedlings when tested at the East Malling Station proved to include one or two in which the immunity of one parent was combined with the stock-producing habit of the other, and these are now being subjected to large scale tests both at home and in the Dominions. Much remains to be done, but it is reasonably certain that the stocks of the future will no longer harbour the woolly aphis below ground, thus rendering its eradication in our orchards a comparatively easy task.

But, though breeding immune varieties is the most effective way of combating plant disease, as it is obviously the cheapest, since it dispenses with spraying methods, the plant breeder cannot *create* immunity. He has first to find it either in some existing variety or in some allied species; it may then be possible to introduce this character into the assemblage belonging to the commercial races. Hence the justification for going back to some of the wild species and primitive varieties, for they may contain a character of value that has dropped out during the building up of the cultivated race. It is now known that " mutations," the changes in the fundamental nucleus material of the organism that occur on rare occasions and give rise to new characters, may be induced with much greater frequency by treatments of a destructive nature short of a lethal dose, such as bombardment with X-rays, heat, &c. The practical results of this method are somewhat remote, because the great majority of mutations must be deteriorations from the standard organism.

It is clear, however, that breeding as a means of dealing with plant diseases is not always practicable, and that methods of direct attack or prevention, such as spraying, will long remain part of the necessary routine of the farmer and gardener. In some cases, the immune variety is still to seek, in others breeding is too slow and complex to offer any prospect of immediate success. It takes something like seven years to bring a seedling apple to the fruiting stage, and, since not a single immunity is required, but protection against many quite unrelated pests, the time and space needed to arrive at the desired apple puts calculated breeding out of count. Moreover, Dr. Moffett's work at the John Innes Horticultural Institution has shown the apple to be a complex polyploid, in which the gene governing a particular character may be repeated as many as six times. In consequence, qualities like colour, shape and size are inherited, not on simple Mendelian lines of absence and presence, but in a graded series of one to six doses. This renders precise realisation of a desired quality impracticable; all that can be done is to breed in the required direction and trust to the keeping up of the character in some of the seedlings. On the other hand, this complex constitution ensures a considerably varying transmission in the fruit generation, as is seen in the inheritance of resistance to woolly aphis.

The measures of control of disease in plants comprise in the first instance the use of fungicides and insecticides, biological control by the introduction of parasites, and what may be termed plant hygiene—the improvement of the environment, either to render the plant less susceptible or to remove the sources of infection. The plant pathology service in Great Britain is considerable. For both entomology and mycology there is a Research Institute at Rothamsted, while the Institutes at Long Ashton, East Malling and Cheshunt, and the Cambridge Horticultural Station each possess a small staff dealing with these problems. The two Agricultural Departments in England and Scotland each maintain a Pathological Laboratory, mainly for advisory purposes, and advice is further afforded by officers stationed at the provincial Agricultural Colleges and at some of the Universities. While it is impracticable to centralise the research work, the Agricultural Research Council has come to realise the need of some co-operation in a general programme, and of the provision for a more fundamental attack on some of the problems than is within the resources of any one of the stations as at present equipped.

The search for an effective fungicide or insecticide can be carried out in several ways. In the first place comes the actual poison, which may be a comparatively simple substance like the arsenical compounds, the copper fungicides of the Bordeaux mixture type, or sulphur in its various forms and combinations. It may be a more indefinite material like the tar and other heavy oils which have proved so effective as winter washes for fruit trees. These substances, discovered empirically, require much investigation in order to ascertain the toxic constituents and to standardise the preparations that may be used in practice, as for example in the excellent work that has been carried out at Long Ashton to define the tar oil washes.

Again the toxin may be of organic origin like nicotine, pyrethrum and derris root. In this field Dr. Tattersfield at Rothamsted has done invaluable work in determining the effective constituents. New compounds are constantly being produced by the manufacturers of organic chemicals, and in this direction the potentialities are so considerable that Imperial Chemical Industries have attached trained chemists in their service to three of the Experiment Stations dealing with these problems. The toxic substance is not the only material essential in a spray fluid; other materials are also needed to add to the spreading and wetting power of the liquid; others again are " stickers," which retain the toxic material on the leaf. These again are in the province of the manufacturers of fine chemicals.

Still another aspect of the fungicide-insecticide question is its application to the plant. Since the war, spraying machines have been improved out of all recognition by the introduction of motor driven pumps working up to pressures of 200-400 pounds per square inch, and British manufacturers are now supplying some of the most effective machines available. There are still openings for investigation in the design of these machines, particularly as regards the nozzles, which are required at times to produce sprays with a certain weight and penetrative power, at others to produce a fine mist that descends like a dew on the plants. It should be realised that, in all such work, investigation in the laboratory must be associated with field trials; not only have the toxic effects to be measured, but the physiological disturbance to the growth of the plant requires study. The period at which the spray is effective may be limited; on the other hand, damage to the foliage may follow with certain materials, particular varieties or the stage of growth of the tree. Finally, the question of dusting powders instead of liquid sprays requires further study.

Biological control has not become general in British horticulture. The two cases of success have been the distribution of the parasite attacking woolly aphis from the laboratory at Farnham Royal that was maintained by grants from the Empire Marketing Board. This parasite has proved only intermittently effective, since, after destroying the woolly aphis on the upper growth of the trees, it generally dies out for lack of food, while the trees become re-infected by migration from the roots. The " white fly " pest of greenhouses can also be controlled effectively by a parasite, which can now be obtained from the laboratories of the Royal Horticultural Society at Wisley.

There remains, however, one class of diseases which is not amenable to treatment—the virus affections of plants, the nature of which has only been recognised within this century. The diseases appear to be increasing in intensity and in the range of plants that are attacked. The colour change in tulips, known as breaking, has been familiar for more than three hundred years, though only within the last few years has its origin from a virus infection been demonstrated. It is clear from contemporary descriptions that virus diseases were present in potatoes in the Eighteenth Century, but in most plants the recognition of their presence is recent, so recent in some cases that exact determination of a virus as the cause of the appearances is yet lacking. To what degree some of these virus diseases are " new " cannot be decided, but that they have of late become vastly more general in their attack cannot be doubted.

The fundamental study of these diseases is exceptionally difficult, both because they are ultra-microscopic and because they cannot as yet be cultivated outside the living organism. The workers at Rothamsted are studying the general aspects of the virus problem, and are in constant touch with the investigators at the Institute of the Medical Research Council at Mount Vernon, Hampstead, who are dealing with virus diseases in animals and human beings.

It is characteristic of the viruses that in most cases they do not immediately kill their hosts; indeed virus infected tulips are known which have carried on vegetatively for more than two hundred years. The infected plants are weakened, and their productivity is reduced; one is familiar with potato stocks which, though riddled with virus, continue in cultivation with a yield of about one half of that which the variety should give. As far as has been observed, a plant once infected never recovers, and, as the disease exists in all parts of the plant, all forms of vegetative reproduction by cuttings, buds, grafts, &c., only multiply the infected material. In many cases however the infection is not transmitted to the seed, in which case, with suitable precautions, a clean stock can be built up from seed. In nature as a rule the infection is spread by an insect carrier, which often is strictly specific and associated with one virus and one host plant only.

This brief outline will indicate the baffling nature of these diseases. None of the ordinary methods of treatment have the least effect upon them. The only effective method is to rogue drastically, and to work up a fresh stock from uninfected plants. In this way East Malling has been able to establish clean lines of raspberries and black currants, and Cheshunt can supply its members with seed from virus-free tomatoes. Seed potatoes from certain districts of Scotland and Ireland, and again from selected areas in England and Wales, are relatively virus-free, because of the absence of the carrier aphis. The value of " Scotch seed " is universally recognised by even the smallest potato grower; if continuously grown on in the South of England, the cropping power of the variety may be reduced by one half. Nucleus stocks of virus-free potatoes have, however, been established by Dr. Salaman at Cambridge.

Since all treatment of virus-affected plants is unavailing, research has to be directed on the one hand to breeding varieties which, if not immune, are not seriously deteriorated by infection, and on the other to the study of the carrier. When the carrier has been identified and its life history worked out, it may be possible to attack it directly when breeding on an alternative host, or to find some deterrent that will keep it away from the crop to be protected. Investigation on these lines is but little pursued, and, in view of the immense economic damage caused by virus diseases, there is justification for greater effort and a varied attack upon some of the problems presented.

At the present time virus diseases cause serious difficulties in the cultivation of Potatoes and other Solanums, Tomatoes, Tobacco, Sugar Cane, Abutilon and kindred genera, Hops, Raspberries, Black Currant, and in many bulbous plants—Tulip, Lily, Narcissus, Iris, Gladiolus, Freesia—though the presence of virus has not been scientifically demonstrated in some of the latter. The fundamental investigations on the nature of viruses, their identity and relation to the carriers cannot be hurried, but there is immediate occasion for more work on the life history and distribution of the carriers, whereby the sources of infection may be dealt with in practice.

The catalogue of plant diseases does not end with the viruses; attacks of nematode worms are proving dangerous in certain places to the cultivation of potatoes and sugar beet. Investigations on this subject are being made at the Institute of Agricultural Parasitology under the London School of Hygiene and Tropical Medicine, and involve the study of soil conditions. A Sub-Committee of the Council has been examining this work, and further consideration is therefore deferred.

Turning now to the effect of the environment upon the plant, the main principles of plant nutrition were determined many years ago by the now classical Rothamsted experiments. Many points of importance still remain for investigation, such as the balance of nutrients required by particular plants and the effect of individual constituents upon the structure and development of the plant at particular stages of growth.

The advent of new fertilisers, particularly the synthetic compounds of nitrogen, continually calls for examination of their value in the field and of any secondary effects upon plant and soil. The careful work at Rothamsted on barley, carried out in conjunction with the Institute of Brewing, has, for example, demonstrated the importance of an adequate supply of nitrogenous fertiliser for the newer barleys in opposition to the older view that barley for malting should be grown on land relatively poor in available nitrogen. Work of this kind is being actively pursued at Rothamsted, while the Institute for Plant Physiology at the Imperial College deals more fundamentally with the course of nutrition in the plant. Latterly also attention has been drawn to the possibility that elements other than those normally regarded as essential to the plant may yet play a necessary part in nutrition, even though they are to be found in plant and soil in relatively infinitesimal proportions. At Rothamsted, for example, it has been demonstrated that boron is essential to the growth of certain plants, and the investigation is being extended to other elements both at Rothamsted and East Malling.

While the broad lines of manurial treatment have been worked out for the agricultural crops, much has yet to be learnt about the specific requirements of fruit and vegetables, especially in view of their growing importance in this country. So far as fruit is concerned, the work of the Long Ashton Station has been of the greatest value to the practical fruit grower. Not only have the specific requirements been determined, but the work of Wallace now enables us to correlate particular deficiencies with characteristic appearances in the leaves and other parts of the plant. Thus the manurial treatment may be strictly checked by observation of the plantation.

The supply of nutriment may also to some extent be controlled by management of the plantation; for example, experiments at East Malling have demonstrated the value of a temporary grassing down, to check the vegetative development and bring into bearing a young apple plantation, though the persistence of the grass covering may be followed by nitrogen starvation. The effects of manuring and of the management of fruit plantations extend both to the flavour and keeping quality of the fruit under ordinary conditions and in cold storage.

But perhaps the chief field for investigation on the nutrition of plants by fertilisers lies in connexion with pasture land. The practice of the intensive manuring of grass land by repeated dressings of nitrogenous fertilisers was initiated by Dr. Warmbold of Hohenheim, its object being the continued production of young grass rich in protein, such as normally characterises the spring flush of May and June. The practical application of the method to British conditions is being worked out through the experiments and propaganda maintained by Imperial Chemical Industries.

Meantime, the chemical composition and feeding value of young grass is being studied at the Institute of Plant Physiology at South Kensington and the Institute of Animal Nutrition at Cambridge. The whole question is of immense economic importance to British agriculture, both because of the continuing extension of the area under grass and of the commanding position of live stock in our farming. The end desired is to render the grass land farm independent of purchased feeding stuffs, since it has been demonstrated that high grade fodder for winter feeding, whose productive value is equivalent to that of cake, can be obtained by drying the young grass. Investigation is proceeding on drying apparatus, suitable on the one hand for the small farm and on the other for the industrial production of fodder on a large scale. Alternatively the preservation of the grass by modified silage processes is also being studied.

The water supply of the plant, of equal if not greater importance than that of fertilisers, is bound up with the study of the soil and of cultivation, and is dealt with elsewhere. The control of temperature and of illumination is only practicable in cultivation under glass, and, while no specific enquiry into these problems is going on, they enter into much of the work of the Cheshunt Station. The electrical heating of the soil of greenhouses offers many advantages. Its practical utilisation will be determined by economic considerations of the cost of electricity, the capital outlay on the installation and its working life in the soil.

EXAMINATION OF PRESENT RESEARCHES

Procedure

The Plants and Soils Committees held their first meeting jointly on 17th December, 1931, and for most purposes they have continued to meet in joint session. During the period under review, they began their part of the general survey of agricultural research undertaken by the Council.

As regards subjects for immediate enquiry, the Committees decided that an enquiry into work on the virus diseases of plants should be made, and that, for this and other entomological purposes, Mr. J. C. F. Fryer, Director of the Plant Pathology Laboratory of the Ministry of Agriculture and Fisheries, should be invited to join the Committee. Subsequently, in 1932, a special Sub-Committee was appointed to make this enquiry, on which Dr. G. H. Pethybridge, of the Ministry's Plant Pathology Laboratory, consented to serve.

To another Sub-Committee, appointed in 1932, was allotted the task of surveying the work in progress on insecticides and fungicides, and of considering whether, with the limited funds available, an attempt could be made to fill in, to some extent at least, the important gaps in knowledge which exist.

Mr. E. M. H. Lloyd of the Empire Marketing Board conferred with the Committees in 1931 on grants from the Empire Marketing Board for research falling within their scope.

There was danger that these grants might seriously be curtailed, and, in the opinion of the Board, it was very important, both for Great Britain and the Empire, that the work on virus diseases at Rothamsted, the work at the East Malling Fruit Station, and the investigations on grassland at Aberystwyth should be continued. After the end of the period covered by this Report, the Council was called upon to advise the Departments of Agriculture and the Development Commission upon the future of those researches carried on by grants from the Empire Marketing Fund, which were not thought by the Council of the Imperial Agricultural Bureaux to be suitable for aid on a co-operative Imperial basis.

The Committees also considered various applications referred to them for advice by the Development Commissioners.

PLANT PHYSIOLOGY

Imperial College of Science and Technology, London University; Research Institute in Plant Physiology.

Some of the work being done on plant physiology in Cambridge, is described under the head of animal nutrition (see p. 96).

The Research Institute in Plant Physiology, at the Imperial College of Science and Technology, London, was founded under a scheme framed by the Development Commissioners in 1911. A grant of £5,000 was made towards the cost of providing acommodation and equipment in the new buildings of the Botanical Department. The annual maintenance grant to the Institute from the Development Fund is now about £6,200.

The Institute was visited by the Plants and Soils Committees of the Agricultural Research Council in June, 1932. Professor V. H. Blackman, who holds the Chair of Plant Physiology and is Director of the Institute, explained to the Committees that the general work of the Institute was directed to the study of the physiological processes underlying crop production. In addition to the Director, the Institute had four graded workers, and its association with the College and the University was of great help in research. At that time 22 workers, about half of whom were post-graduate students, were at work in the Institute. In the summers, members of the staff and students spend periods at Institutes in the country such as Rothamsted, East Malling and Cheshunt. Two main ideas run through the work: (1) the physiological processes by which the crop is built up, measurements being made of curves of growth, increase in leaf area, rate of tillering, etc.,

(2) the inter-relation of the different factors in plant growth and yield, e.g., the response to light as affected by temperature and *vice versa.*

For some years studies have been made of what is called " electro-culture "—i.e., the effect on crops of a high tension overhead discharge. In pot cultures of growing barley an increase in yield of the order of 15 per cent. had sometimes been secured. The best effect seemed to be obtained by electrifying during the second six weeks of growth, just before the plant came into flower, but results were often inconsistent, and more work was needed.*

The application of the results of physiological studies found a very satisfactory field of work in glasshouses, in which it was possible to control temperature, light and humidity. Hence the advantage of collaboration with the Institute at Cheshunt, where they were examining leaf activity to find the best time of application and the best balance of manuring.

Dr. F. G. Gregory, the Assistant Director, had, for ten years, been studying the physiological effects of fertilizers on plants—e.g., the results of applying nitrogen, potash and phosphorus to the plants grown in sand in pots on such factors as tillering-rate and growth of leaf surface. Nitrogen was the most important element in the growth of a plant; it was taken up at an early stage during the first six weeks of growth. After that period it produces no additional yield, but increases the nitrogen content of grain and straw. Nitrogen and phosphorus do not affect the assimilation rate, but absence of potash leads to a reduction. Dr. Gregory was also studying the effect of deficiencies of the three manures on carbon assimilation and respiration. The effects of manurial deficiencies on nitrogen metabolism too are very marked, a deficiency of potash leading to a big increase in amino-acids. He was also studying ear formation in barley, and the assimilative power of different varieties. The variety Archer was more efficient than Plumage in the use of nitrogen and phosphorus, but Plumage was more efficient in the use of potassium. The hybrid Plumage-Archer inherited the high efficiencies of both parents. These results were being tested on the farm scale by the Rothamsted staff at Woburn.

In the Biochemical Department of the College, Dr. A. C. Chibnall, with the help of a grant from Imperial Chemical Industries, was making biochemical analyses of pure strains of pasture grasses, measuring by weight the contents of crude protein, and investigating also the amino-acids of the protein, about which in grasses little is known. In 1931, while on unmanured plots the protein contents were between 8 and 12 per cent., on plots treated with ammonium suiphate the crude protein at the first weekly cutting was 43 per cent., and at the second cutting 40 per cent.

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* The Agricultural Research Council propose to undertake a special enquiry into the possibilities of this work in the near future.

This work is obviously very closely connected with some of that going on at the Animal Nutrition Institute at Cambridge, especially with the investigations of Mr. Foreman and Dr. Woodman. More co-operation between different Institutes seemed to the Committees desirable.

PLANT BREEDING

Plant Breeding Institute, Cambridge

The first and most striking application to agricultural crops of the re-discovered principles of Mendel was the development by Sir Rowland Biffen of new types of wheat, in which various desirable factors, such as high cropping power, resistance to rust and good baking qualities are some or all of them combined. Such Cambridge wheats as Little Joss and Yeoman are well known to arable farmers. Similar work of great value to agriculture has been done for barley by Dr. E. S. Beaven on his private experimental station at Warminster.

In order to give additional facilities for plant breeding, land and buildings for an Institute at Cambridge were provided in 1912 as part of a scheme for developing the School of Agriculture, for which a grant of £18,000 was made from the Development Fund. By a further grant of £21,500, made in 1924, the accommodation in the School was again extended.

The Plants and Soils Committees of the Agricultural Research Council visited the Institute in July, 1932. The staff were still paying more attention to wheat than to other kinds of cereals, the qualities now under consideration being stiffness of straw, to prevent laying in rain and wind, resistance to disease (particularly rust) and quality of grain as assessed by millers and bakers. A wheat with stiff straw and grain equal to that of Yeoman II had recently been produced, and investigations were proceeding with soft wheats suitable for biscuit making—a very important British industry. Mr. A. E. Watkins was crossing rivet wheat with other English wheats and using spelt wheats to obtain winter hardiness. Professor F. L. Engledow had produced a wheat with grain quality distinctly better than that of Yeoman II. Some of these new wheats were nearly ready for distribution.

As in the case of wheats, the staff had collected barleys from all over the world and tried them for crossing. They had produced new varieties as good as, but not better than those existing. Beaven's Plumage-Archer and Hunter's Sprat-Archer were still the two outstanding varieties. Some years ago they found a stiff strawed barley, and raised from it a number of crosses which were heavy yielders of good feeding barley. But the grain was bad for malting, and it appeared that stiffness of straw was a Mendelian quality linked with bad malting properties. They were also crossing six-row barleys with English two-row barleys, and were confident that in some of the crosses the malting quality was as good as in two-row barleys.

As regards oats, the chief problem was to produce winter oats that would stand up to rough conditions, and Dr. H. Hunter was crossing winter hardy forms with an Argentine oat, and getting promising results in many southern and south-eastern counties. Farmers would prefer to grow winter oats, so that attacks by frit-fly might be avoided. So far, the Institute had met with no success in attempts to breed varieties resistant to frit-fly. On this problem Dr. N. Cunliffe is also engaged at Oxford.

Mr. Watkins was trying to find strains of sugar beet which would be reasonably fertile with their own pollen, and so maintain themselves under ordinary conditions of seed production. Professor Engledow was isolating a number of pure lines of peas, and breeding other short-strawed forms. Dr. Hunter was breeding pure lines of the field bean, with which little work of improvement had hitherto been carried out. Experiments on the breeding of other crops, for example swedes which would resist finger and toe disease, were also going forward.

The Committees were well satisfied with the work of the Plant Breeding Institute.

Welsh Plant Breeding Station

The Welsh Plant Breeding Station at Aberystwyth was founded in 1919 with funds provided by Sir Laurence Philipps, Bart., who gave a capital sum of £10,000 as an endowment for maintenance and £1,000 a year for ten years. For buildings and a farm £11,400 was found by the Development Fund, and £10,200 raised by subscription. The Development Fund also provides about £8,000 a year for maintenance.

The Agricultural Research Council did not visit Aberystwyth during the period under review, and only a short summary of the work will here be inserted.

The problems of plant breeding, especially from the point of view of hill pastures, are being attacked by Professor R. G. Stapledon and his staff, consisting of 3 plant breeders with assistants. Professor Stapledon, since he went to Aberystwyth twenty years ago, has done such notable work on pasture plants that his methods and results have not only greatly stimulated pasture improvement in these islands, but have attracted notice throughout the Empire and in other countries.

The basis of the work of the Station has been the examination of the varying material presented by any wild species and the selection of individual plants showing promise of value for grazing, such as a leafy habit of growth, vegetative development early or late in the season, etc. These individuals are propagated as clones until they can be tested against one another, after which selected strains are further developed for seed production. After long testing, several strains have already reached the commercial stage and are in the hands of farmers, while a number of others, which have been further improved, are now under trial. In addition to this method of selection and clonal propagation, breeding work is also in progress. Dr. T. J. Jenkin is engaged in a systematic study of rye grass and some interspecific hybrids, and Captain R. D. Williams is working with clovers, particularly red clover. Mr. E. T. Jones deals with oats, endeavouring by selection and breeding to establish a variety suitable to the high altitudes and rainfall of much of the Welsh arable land.

The work now in progress may be grouped under four headings: the raising of new plants, the production of their seed in adequate quantities, the testing of the results, and advisory work for the introduction on Welsh farms of the knowledge gained, largely by means of demonstration plots.

Further details will be given in the next Annual Report.

Scottish Plant Breeding Station

This Station also was visited by a Sub-Committee of the Agricultural Research Council after the date of closing this Report and will be dealt with in detail next year. Its work consists chiefly in promoting the discovery and establishment of such new varieties of crop plants as are suited to Scottish conditions.

The Scottish Society for Research in Plant Breeding was registered in 1921, when over £20,000 had been raised from Scottish farmers and other private sources. Subsequently a state grant of £22,500 on the £ for £ basis was made from the Agriculture (Scotland) Fund. A property at East Craigs, Corstophine, near Edinburgh was bought, and an endowment fund established. A grant towards maintenance of about £1,500 a year is now made from the Development Fund.

HORTICULTURE

John Innes Horticultural Institution

The John Innes Horticultural Institution is concerned primarily with the study of pure genetics and cytology, and it is only incidentally in the search for knowledge that a few plants of horticultural value have emerged and been distributed. Nevertheless, contacts with economic problems become numerous in the course of breeding experiments with fruit trees. By long continued investigations, the varieties of apples, pears, cherries and plums in commerce are being characterised as self sterile or to a greater or less degree self fertile, and the relationships that will permit of cross fertilisation are being determined. The questions of sterility often depend upon nuclear constitution, and the Council is making a grant to the Institution for the maintenance of a cytologist dealing specially with fruit.

Dr. C. C. Hurst has long been known as an independent worker on genetics. Latterly he has been investigating the complex relationships of the genus Rosa, long a matter of difficulty to taxonomists. By cytological examination and studies of the embryco sac formation of material collected in all parts of the northern hemisphere, Dr. Hurst has evolved a scheme which derives the known species from six primitive species, each giving rise by polyploidy to more complex derived species. The economic interest of the investigation lies in the guidance the conclusions give to the breeder of roses, and the possible value of the fruits of some of the hybrids. The Agricultural Research Council awarded grants to Dr. Hurst (through the John Innes Institution) of £400 in 1932 and £300 in 1933.*

Kew Gardens

While the scientific work carried on at the Royal Botanic Gardens does not fall directly under the review of the Council, a visit was paid by the Council to the Herbarium, which is collaborating in some of the work carried on by Mr. Marsden-Jones, to whom the Council has made grants (see p. 64).

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* During 1934 Dr. Hurst finished his work, but he has given to the Institution his valuable collection of plants.

Horticultural Research Station, Cambridge

In 1923 a grant of £1,720 from the Development Fund on the £ for £ basis was approved in aid of capital expenditure for the establishment of a Horticultural Research Station at Cambridge, the University providing land on one of the Farms of the School of Agriculture. In 1931 a further grant of £600 was made for laboratory accommodation and apparatus. The maintenance grants now amount to about £4,000 a year.

The Station, under its Director, Mr. D. Boyes, was concerned at the beginning with fruit as well as vegetables; but it soon became obvious that work on the former subject must grow beyond the resources of the Station, while it was also being dealt with at East Malling and Long Ashton. The investigation of fruit was consequently dropped, with the exception of that on strawberries. As regards the improvement of vegetables, the Station has neither staff nor land enough to enable it to attack the problems by fundamental genetical studies. The basis of the work thus inevitably became selection for particular characteristics.

Commercially it is almost impossible to obtain pure breeding stocks of the varieties of vegetables, though among commercial stocks may be found material suitable as a basis for pure lining and further breeding. For example, individuals among onions resistant to pink rot have been discovered, and may become the foundation of economic strains. The Station has also been devoting attention to peas for canning, Roscoff broccoli, Brussels sprouts, cabbages, parsnips and gherkins. The broccoli bred at Cambridge have been grown on at Hayling Island. The staff has also investigated the physical and chemical problems of spraying.

Certain funds have been provided for the Station by the trade, which is represented on the Committee of Management. The relations of the Institute with the trade were considered by the Syndicate appointed by the University to report on its relations with the Agricultural Research Institutes,* and certain changes in those relations and in the management of the Institute have now been made.

The Plants and Soils Committees of the Agricultural Research Council, which visited the Horticultural Institute in July, 1932, point out that the response of varieties to soil and climate is greater with vegetables than with normal farm crops, and that, therefore, the Station should extend its experiments into contrasted areas rather than take much more land locally. This extension can best be secured by co-operation with other Institutes, Colleges and county agricultural staffs.

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* See page 97.

In view of the enormous field of enquiry, the Committees hold that the work should be confined to a few selected subjects in turn, choosing them chiefly for their economic importance. Beginning with comparison and selection, breeding from individuals will follow, to establish pure stocks and to maintain them pure. The technique by which the purity of these stocks can be maintained under British conditions also requires study. But the work of the Station should assist the horticulturists of the country, especially in the eastern counties, to develop seed-growing, and so diminish our present dependence on California, France and Italy, for much of the commercial seed.

As regards entomological and mycological work, the Committees recommend that attention should be concentrated upon susceptibility and resistance. They suggest as of immediate importance in entomology the study of the carrot fly and pea moth, and in mycology the disease of the onion, the pea, and ring spot in lettuce. They think work on strawberries is not necessary at an Institute chiefly devoted to vegetables, especially as strawberries are being investigated elsewhere. Problems of cultivation and manuring should be discussed with other workers. Problems of spraying are being attacked at Rothamsted, East Malling, Long Ashton and Wye, and call for a comprehensively planned scheme of research that allots to each centre which is advised to continue a share in the general campaign.

Cheshunt Station

Experimental and advisory work on glasshouse crops is carried on at a Station situated at Cheshunt in Hertfordshire. The Nursery and Market Garden Industries Development Society was formed in 1913 by the Growers of the Lea Valley, and, beginning in 1914, grants amounting in all to just over £12,000 have been made from the Development Fund towards capital expenditure, the growers finding an approximately equal sum. Grants towards maintenance have also been made, about £5,000 a year from the Development Fund and grants for special researches from the Empire Marketing Board.

The Society has been well supported by the trade. In 1932 there were 360 members, who paid subscriptions of two guineas per acre of glass cultivation, while contributions are also received from the County Councils of Hertfordshire, Middlesex and Essex.

The Station was visited by the Plants and Soils Committees of the Agricultural Research Council in February, 1932. Dr. W. F. Bewley, the Director, explained that, besides advisory work, the staff undertook experiments on tomatoes, cucumbers and vegetable catch crops, and also on chrysanthemums, roses and other florists' crops grown on a large scale under glass.

Recently the staff have been not only carrying out manurial trials, but also studying the effects of changes in the physical environment, such as the water supply, the texture and temperature of the soil, and the relation between soil and air temperature. In commercial conditions, a tomato grower might raise 70 tons per acre during the first year on new soil, and find the yield gradually drop to 30 or 40 tons. This decrease can be largely prevented by sterilizing the soil with steam, and lightening it by green manuring or by adding straw or peat. Certain advantages are also obtained when the heat is applied to the soil instead of the air as is the usual practice, and observations were being made on the cost of various methods of heating.

Diseases of glasshouse plants are sometimes very serious. For instance, in 1906 the local cucumber crop was practically wiped out by the spread of a violent attack by a fungus. But a single plant was observed to be growing in a house in which all the others had been killed. Seed from this plant proved to be immune, and became the source of the varieties now most generally grown. Recently, disease had reappeared in this variety; possibly some non-immune strains have been allowed to emerge.

Virus disease in tomatoes can be controlled by using clean seed from virus-free plants, and Dr. Bewley was able to supply the members of the Association with clean seed raised from plants protected from infection. On occasions, virus diseases are carried by white fly, and there were some indications that red spider was guilty too, though probably the chief agent was the nurseryman, who might carry infection on his hands, while it easily spreads from plant to plant. Mr. B. D. Bolas was studying the abnormal physiology of tomatoes as regards starch and sugar metabolism—the infected plant does not get rid of its starch by night. The work on virus diseases had been carried on by the help of a grant from the Empire Marketing Fund.

Attacks on roses, chrysanthemums, cyclamen and onions are made by diseases probably carried by the insects known as thrips. Attempts were being made by Mr. E. R. Speyer to control the pests with naphthaline and nicotine. Since 1926, the Station had been distributing a parasite of the white fly.

The Station is thus concerned with problems that may be purely scientific or matters of management. For example, Dr. Bewley's desire to find employment for tomato houses in the winter season led on the one hand to the breeding of a new variety of lettuce and on the other to the study of conditions of soil heating, watering and management, the benefit of which extended to the succeeding tomato crop.

The Committees considered that the Station was carrying on well the special types of advisory and practical experimental work for which it was designed. A Sub-Committee has recently visited the Station, and a more detailed report will soon be available.

Miscellaneous Work

A careful investigation of the stability of the variation to be found in native British plants under different soil conditions has been conducted for some years by Mr. E. M. Marsden-Jones at Potterne, in Wiltshire. This work is of interest to taxonomists and also to plant breeders in general, and Mr. Marsden-Jones had been collaborating with both Kew and the John Innes Horticultural Institution.

On the recommendation of members of the Agricultural Research Council, who were personally familiar with these investigations, the Council awarded a grant for one year of £100 to the John Innes Institution in aid of the continuation of Mr. Marsden-Jones's work.

FRUIT RESEARCH

Horticultural Research Station, East Malling, Kent

Research on fruit is becoming of more and more importance as the growth of fruit increases in England. The chief places where experimental work is going on are East Malling, Long Ashton and Wisley.

The East Malling Experimental Station, founded in 1913 by local effort, in connection with the South Eastern Agricultural College at Wye, was enlarged in 1919 when it received a grant of £4,650 from the Development Fund on a £ for £ basis. As work extended, further grants (about £26,000 in all) towards capital expenditure were made from the Development Fund. Enlargements of the Station have also been financed from the Empire Marketing Fund and local subscriptions. The Station is maintained chiefly by grants from the Development Fund and, till lately, from the Empire Marketing Fund. In 1932-33 the income from these two sources was about £15,000.

A preliminary visit was made to the Station by the Plants and Soils Committees of the Agricultural Research Council in July, 1932. At a later stage, during 1934, the Station has been examined in greater detail; but the first visit sufficed to show the interest and importance of the work being done by Mr. R. G. Hatton, the Director, and his staff.

The problems studied were those, or derived from those, brought to the Station from outside, especially by commercial fruit growers. Thirty years ago very little scientific knowledge about fruit growing existed; the success obtained by experience and observation was still subject to unexpected failures. Even in experimental work, the variations from tree to tree were often greater than can be induced by differences in manuring.

The subjects of the work of East Malling are divided into two groups; (1) small soft fruit, grown on its own roots; (2) hard fruit, of which 99 per cent. is grown on foreign root systems. The first essential was to establish true clonal material of each recognised variety, for it was found that the varieties in commerce were often not true to name, but were mixed with chance seedlings of inferior cropping value, which might even be sterile, or infected with disease.

In soft fruits, such as raspberries and black currants, varieties tended to lose value—the fruit grower describes it as " reverting ", " running out " or " going wild ". This was traced to the effects of disease, and one of the first successes of the Station, which won for it the support of practical men, was the establishment of a source of disease-free stocks.

A technique has been devised which gives an accurate measure of cropping capacity, disease resistance, etc. Thus, earlier and more prolific varieties have been isolated, e.g., in black currants and raspberries. Among many new varieties of raspberries, 40 were under examination. In strawberries, some of the factors involved in disease had been distinguished.

In plant breeding it is, of course, necessary to remember that varieties selected for their value as fresh fruit are not necessarily those best for the new industry of canning. One difficulty in breeding for canning is the large sample needed for experimental examination—about 12 lbs. three times repeated. Close co-operation is maintained between East Malling and Long Ashton, Chipping Campden and Wisley, and help in the chemical problems of spraying has been given by Dr. Tattersfield of Rothamsted. The variety testing, once so necessary at East Malling, can now be left to the National Fruit trials at Wisley.

The work on hard fruit is specially concerned with root stocks. When these investigations started, East Malling began upon the classification of the clonal stocks reproduced by layering, leaving the seedling stocks to Long Ashton, but, with progress, each place naturally extended into the other's original territory. While the fruit grower is only concerned with the mass differences produced by different stocks, it is necessary for science to investigate the underlying effects upon the physiology and chemistry of the plant.

Trees can be made giant or dwarf at will by changing the stock, with great differences in cropping power and dates of maturity. Root growth is observed in pits, excavated to show the soil profile protected by glass. This side of the work is in the hands of Dr. R. C. Knight, the Assistant Director. The experimental unit now consists of 8 trees, each tree representing one " plot " in a Latin square or other randomized arrangement. The root stocks themselves show no mutations, though they vary in their habit; some appear to have remained constant since the 17th century.

Long Ashton Fruit Research Station

A detailed account of the work at Long Ashton will appear in the next Annual Report.

The Station was developed from an existing National Fruit and Cider Institute connected with the University of Bristol. A grant of £6,250, and in 1920-22 a further grant of £5,250, were made on the £ for £ basis from the Development Fund for land and buildings. Other capital grants of £9,700 in all followed. For maintenance, the Development Fund provides about £14,000 a year, while grants for special researches have been made from the Empire Marketing Fund.

The chief investigations are concerned with fruit culture, the diseases of horticultural crops, fruit preservation and fruit products, especially cider. The Director is Professor B. T. P. Barker.

Chipping Campden Sub-Station for Fruit and Vegetable Preservation

Early in the war the importance of fruit and vegetable preservation became apparent, and work was begun by the Ministry of Agriculture with grants from the Development Fund. In 1918 it was decided to concentrate the work at Chipping Campden. Capital advances of about £20,000 were sanctioned, and in 1921 the Station was handed over to the University of Bristol, with a grant of £4,500 for working capital.

The Station, under the direction of Mr. F. Hirst, is primarily concerned with the establishment in this country of a fruit and vegetable canning industry on scientific lines, and the work will be described in detail in the next Report.

Low Temperature Research Stations at Cambridge and and Ditton, Kent

These Stations are under the control of the Department of Scientific and Industrial Research, and thus, speaking strictly, are outside the purview of the Agricultural Research Council; but it is inevitable that much of their work should be of interest to agriculturalists, and when representatives of the Council visited Cambridge in 1931, they were shown over the Station by the courtesy of the late Sir William Hardy, the Director of Food Investigation.

The aim of the two Stations is to study scientifically the problems which underlie the preservation and transport of food, whether meat, fruit or other food stuffs.

Although part of the work is concerned with the problems of over-sea supplies, the number of cold stores owned by farmers and others in this country is continually increasing, and the results obtained by the Stations are of interest also to home producers, retailers, and consumers. We may give in short form one or two examples.

The cold storage of home grown apples has presented difficulties. The majority of such apples will not tolerate prolonged exposure to temperatures as low as 32°-34° F., which are needed for the longer periods of storage. Experiments at the Stations show that the difficulty can be overcome by appropriate manurial treatment of the trees, and by reinforcement of cold storage at the moderate temperatures of 38°-42° F. by control of the oxygen and carbon dioxide content of the storage atmosphere.

The plum crop would be increased in value if the fruit could be stored for a period of a few weeks. The optimum conditions for storage have been studied by the Stations, and some fruit growers are obtaining a longer season for marketing in consequence.

The storage of vegetables and soft fruit is also under investigation.

The problems of the storage of meat in prime condition have been the subject of prolonged and, in many respects, successful investigation. A description of the results is, however, not suitable for this Section of the Report. Further particulars of all the work can be found in the publications of the Department of Scientific and Industrial Research.

VIRUS DISEASES OF PLANTS

Appointment of Committee

To examine the work being done in the various Research Institutes on the virus diseases of plants, the Agricultural

Research Council appointed a special Sub-Committee, consisting of Dr. Arkwright and Dr. Butler, members of the Council, together with Mr. J. C. F. Fryer and Dr. G. H. Pethybridge of the technical staff of the Ministry of Agriculture and Fisheries. The Sub-Committee have not yet completed their report.

Rothamsted

The work on Virus Diseases going on in the Plant Pathology Department at the Rothamsted Experimental Station was inspected by the Plants and Soils Committees of the Agricultural Research Council in May, 1933.

The Plant Pathology Department, under Dr. J. Henderson Smith, is now chiefly engaged on the study of virus diseases, hitherto with a grant from the Empire Marketing Fund. The future of this work consequently needed consideration, and the special Virus Sub-Committee of the Council visited Rothamsted in 1934, after the period covered by this Report. As viewed in 1933, the work consisted chiefly of fundamental research on the nature of virus and its movement in the plant. The virus does not travel in the water stream, but from cell to cell in the cytoplasm. An infected plant respires more quickly than a normal plant. Much work on metabolism remains to be done. Each virus seems to have an insect carrier, though a particular species may be a carrier for distinct viruses, and some viruses are carried by more than one species. An important subject of study is therefore the relation of the carrier to the virus. If not a mechanical transmitter, is there an incubation period within the insect; how long does it persist; is it passed on to the viviparous young of the aphis?

According to the Rothamsted investigations, infectivity does not pass through the egg, but lasts through the insect's life; and it seems likely that some multiplication must occur in the insect. It is hoped eventually to grow the virus outside the insect's body. There is fair evidence that a virus is particulate —different viruses can be filtered by membranes with different sized pores. If two viruses are used, a plant disease different from either of those caused by the viruses singly may be produced.

Potato Disease Research Station

The Potato Virus Research Station at Cambridge is administratively a Department of the Plant Breeding Institute, and is under the control of Dr. R. N. Salaman, so well-known for his work on potato diseases. The Department was started in 1926 with the help of a grant of £1,200 from the Development Fund, which has also provided grants for maintenance—recently about £2,700 to £2,900 a year.

The Station was first visited by the Plants and Soils Committees of the Agricultural Research Council in July, 1932.

The main work of the Station has been the discrimination of the several viruses affecting the potato and the characterisation of their effects, singly and combined. Some varieties of potato may carry a dangerous virus and yet show no outward symptoms, thus increasing the difficulty of maintaining healthy commercial stocks by rogueing. To this latter question, the establishment of virus-free stocks, Dr. Salaman has given a good deal of attention. He has also done much work on diseases of the Crinkle and Stocade type and with Mr. F. C. Bawden has differentiated several of these diseases by the symptoms produced when grafted on to different host plants.

Dr. Kenneth Smith, the entomologist, and Mr. J. P. Doncaster, his assistant, were found to be studying the "spotted wilt" of tomatoes and "leaf roll", the potato virus disease of most importance to the farmer. The latter disease is transmitted by one common species of green fly (*Myzus persicae*), which also transmits fourteen other diseases. The various mosaic diseases of the potato are due to a complex of viruses, of which Dr. Smith has identified two of the common components, which he calls the X and Y viruses; he has studied the insect transmission of the latter. This conception of the unit virus and of the combination of units in producing different types of disease has proved most fertile in the advancement of research on potato virus diseases.

Dr. Salaman was also experimenting on the common blight of potatoes, (*Phytophthora infestans*), with immune species and continued selection. A strain immune to the common blight had been evolved, but almost simultaneously a new form of the Phytophthora had appeared, to which the new seedlings were susceptible.

OTHER DISEASES

Useful work on the control of apple mildew has been done by Dr. R. C. Woodward of the School of Rural Economy, Oxford. Dr. Woodward found that the disease only overwinters in buds invaded by the mycelium of a fungus. The period during which fungicides could be applied effectively was while the gap left by the bud-scales at the apices of buds still remained, usually during June.

Various types of fungicide were used. In one case, at least, a non-proprietary spray containing sulphur and casein produced as great or greater percentage decrease in overwintering infections than one of the colloidal sulphur preparations, while sulphur as a dust was much less effective. Lime sulphur destroyed mildew, though the damage it produced on the trees ruled out its use on certain varieties of apple. It was found that the effectiveness of fungicides varied in different places, in different weather, and with different varieties of apple. The School of Rural Economy applied for a grant in order to carry this work to a conclusion, and, on the recommendation of the Plants and Soils Committees, the Agricultural Research Council voted £300 for the investigation.

TESTING AND " GROWING ON "

National Institute of Agricultural Botany

When new varieties of plants are developed by genetic research or selective breeding, it remains to test them on the farm scale and to grow them on till an adequate commercial stock of plants or seed is obtained for distribution to farmers, nurserymen or seedsmen, observation being kept on their qualities meanwhile. This was the primary function of the National Institute of Agricultural Botany, which was founded in 1919. The work, though it cannot be called research, is clearly necessary, in order that the results of research may be applied to industry.

The Institute also tests, by the most modern statistical methods, different varieties of plants, not necessarily new, to discover which are best for British conditions, and, in certain cases, to detect synonyms and reduce the number in use. It has a sub-station at Ormskirk, Lancashire, to test potatoes for disease immunity, and sub-stations for other crops at (1) the Norfolk Agricultural Station at Sprowston, near Norwich, (2) the East Anglian Institute of Agriculture at Good Easter, (3) the Lord Wandsworth Agricultural College at Long Sutton, Hants, (4) the Somerset Farm Institute at Cannington, and (5) the Harper Adams Agricultural College at Newport, Salop.

The National Institute of Agricultural Botany was founded partly by donations amounting to £50,000 from agricultural merchants, millers, other agricultural trades and private benefactors, and partly by funds of about £59,000 provided through the Ministry of Agriculture and Fisheries by the Development Fund. It houses the official Seed Testing Station in its buildings at Cambridge. The Institute is managed by a Council including representatives of the Ministry of Agriculture and Fisheries, the Universities of Oxford and Cambridge, the Royal Agricultural Society of England, the National Farmers' Union, the millers, the seed trade, the maltsters and the corn and agricultural merchants. The cost of maintenance is provided partly by endowments and subscriptions and partly by a grant, about £7,400 in all, from the Development Fund.

The Plants and Soils Committees of the Agricultural Research Council visited the National Institute of Agricultural Botany in July, 1932, having previously studied the Reports of the Institute and material relating to its work and finances supplied by the Ministry of Agriculture and Fisheries.

Mr. W. H. Parker, the Director, described the general aim of the Institute as the improvement in the yield and quality of farm crops by determining the best varieties, and introducing their seed to the trade and to farmers. The Institute had at Cambridge a trial ground of about 76 acres and a granary for cleaning and drying the seeds. The five substations fairly covered the country, except that it would be well to substitute a station in the Fens for that at Good Easter and to add stations in Yorkshire and Wales.

When the Institute was founded, it was believed that a constant supply of new varieties would be received from plant breeders, and that the main task of the Institute would be to test these varieties by means of trials on a field scale, conducted scientifically under different conditions of soil and climate. Secondly, it was thought that the Institute would multiply such of these varieties as appeared to be distinctly better than those already on the market and distribute them through the seed trade.

The number of new varieties submitted for trial has been less than was originally anticipated, and, as a rule, they have not shown sufficient promise to be multiplied. Such negative results are, nevertheless, of value, in that they keep the varieties in question off the market. The only new variety hitherto distributed to the trade is Yeoman II wheat. Lately a number of new varieties have been sent for trial by plant breeders, the most promising being a white winter hardy oat, which has been named "Resistance," bred by the Cambridge Plant Breeding Station and now (1934) being distributed.

The Seed Trade is beginning to send new material to the Institute for testing before it is placed on the market. In the present season 16 types of farm crops are under trial, representing 99 varieties, of which 20 are new varieties.

Although the main purpose for which the Crop Improvement Branch was instituted has proved more difficult to achieve than some of the founders believed, the Council consider that work of high value to the farming community has been carried out in the thorough and efficient testing of existing varieties by uniform methods at Headquarters and at the sub-stations; by the maintenance of pure line stocks of established varieties and their sale to the seed trade in small quantities; and by the efforts made to reduce the number of synonyms used by the trade for the same variety.

These efforts have been most successful in the case of potatoes. As all varieties claiming to be new must pass through the Institute's Potato Testing Sation at Ormskirk for trial, in order to prove their immunity to wart disease, exceptional opportunities arise for detecting synonyms. The Synonyms Committee of the Institute was set up in 1920. In that year 72 per cent. of the varieties claiming to be new were in fact old; Up-to-date appeared under 200 different names. In 1931 only 6 per cent. of the varieties submitted as being new were old, and these were mainly rogues In 1925 no less than 56 synonyms were detected in seedsmen's catalogues, but by 1932 the number noted was only 24. Owing to lack of funds, it has not been possible to do similar work, until recently, on roots. As many as 147 varieties of mangels, and 114 varieties of swedes (Purple tops) have been traced. It is clear that the number should be reduced.

The work which the Institute has done in testing new varieties of crops from abroad, though it has met with some trade criticism, has, in the Council's view, been justified. For instance, the Committees which visited the Institute were informed that the value of certain Swedish oats (Star and Golden Rain) for growing in this country has been confirmed. A lucerne has been introduced from Hungary, which has been shown to be as good as French Provence, so that the farmer is no longer restricted in his choice to one variety. A foreign mangel has proved to be the best hitherto tested, though it has not yet undergone comprehensive trials. The comparative value of different varieties of sugar beet has been tested with the aid of grants from the Beet Factories, who are anxious to find a variety to compete with Kleinwanzleben, which is used by 90 per cent. of the farmers growing beet.

On what may be termed the negative side of the Institute's work, it is noteworthy that the Svalof Plant Breeding Station has removed from its list two new wheats, formerly recommended for this country, because plot trials conducted by the National Institute of Agricultural Botany showed them to be very susceptible to rust. The use of Black Tartarian oats is being discouraged by the Institute, except in the wetter districts.

It is well known that, before the establishment of the Institute, county and other trials of different varieties were conducted by the most diverse methods, and usually by methods which on grounds of scientific precision were open to serious criticism. The experimental error in some of these trials rendered them almost valueless. A work of the highest scientific value and importance has been done by the Institute in securing the adoption of uniform methods of trial, and the Council believe that the methods now employed may be accepted with confidence.

It is generally the practice of the Institute to grow varieties first at Cambridge, or at one of the approved sub-stations in single observation plots. A selection of varieties is then made for accurate trial in replicate plots at the six sub-stations, normally for three years. The seed for these trials is grown either on the Headquarters Ground of the Institute or under the Institute's control; uniform drills are used at all centres, and the Recorder at each Station has been trained at the Institute; the method of trial is the Beaven half-strip method, and the arrangements under which the trial is conducted are carried out according to a plan framed by the Institute. The yield and all other important agricultural features are noted.

As regards quality of grain, wheats are tested on behalf of the Institute by the National Association of British and Irish Millers, who also make baking tests; and barleys are tested and valued by the Institute of Brewing. There is no authoritative outside body to undertake the testing of oats. Quality is, therefore, estimated by the Institute by husking and working out the proportion of husk to grain. A collection of all cereals of economic importance is maintained in small plots at the Institute's Headquarters, and samples are supplied to breeders and to museums.

A beginning has also been made in growing plots of cereals to enable synonyms to be detected. The Institute further maintains 100 stock plots of different varieties (old and new) to be marketed in small quantities as pure stocks.

The Committees of the Agricultural Research Council were satisfied with the work being done.

IMPROVEMENT OF GRASS LAND

Recent History

Till comparatively recent times, much more attention was given to the cultivation of arable land than of meadow and pasture. Save for an occasional spreading of farmyard manure and harrowing, grass was expected to grow itself.

The earlier work on the improvement of pasture land arose out of the discovery of basic slag and of its beneficial effect in promoting the growth of white clover, when applied to grass land in a finely ground condition. After Somerville's careful demonstrations at Cockle Park, this became the accepted method of improving the character and the grazing value of pastures on heavy clay soils in particular. The remarkable stimulation of the growth of white clover by the phosphates and lime of the basic slag led to the accumulation of nitrogen from the atmosphere, and with the grazing a cycle of increasing fertility was set up at a minimum of cost.

But after the war British scientific men were introduced to a new conception of grass land management, which had been worked out by Dr. Warmbold of Hohenheim, in order to supply from grass alone the fodder of high protein content which milch cows require, but which Germany could not obtain during the war. Whereas, as a result of experiments in this country, it was commonly supposed that the use of nitrogenous fertilisers deteriorated rather than improved the feeding value of pasture, Warmbold claimed successful results from the application of quantities like a hundredweight per acre of sulphate of ammonia at intervals of a month or so from early spring to the end of the season. The essence of the systems consisted in grazing down the herbage before it grew to a height of more than six inches, and resorting to cutting, if the season gave an excess of grass for the stock available. It was stated that the young grass thus produced had always a high protein content and digestibility, extending the season of productive grazing at both ends.

The remarkable nutrient qualities of young grass, to which Warington at Rothamsted called attention fifty years ago, have been fully demonstrated recently by the careful investigations of Wood and Woodman and their colleagues at Cambridge, by Shutt in Canada and the Imperial Chemical Industries staff at Jealott's Hill. Young grass is a food which for equal dry weight is almost equivalent to linseed cake in protein contents, while it contains also vitamins and other special accessory food factors. Its qualities can be preserved by drying. The presence of the valuable constituent carotin is shown by the yellow colour of butter from cows fed on fresh or dried young grass, which had been stimulated in growth by nitrogenous manures at Jealott's Hill.

The long-term effect of this treatment on the grass land itself is still under investigation. Recent experiments carried out at Longleat, under the direction of the University of Bristol, showed that, in accordance with general experience, intensive grazing without manurings or with nitrogenous manures alone brings about a deterioration of pasture, while in conjunction with complete manuring it causes improvement in the herbage and sward. Meanwhile the changes induced immediately in the botanical nature of the pasture by different treatment, and especially by different times of grazing, are well shown by experiments at Aberystwyth and others at Jealott's Hill. It is possible to produce almost any required change in pasture at will, and to secure a growth of good feeding quality throughout a normal season.

Finally, the physical treatment of grass land is of great importance. Very severe harrowing, even to the extent of apparent injury to the sward, induces later on an improved herbage. This result has been obtained by many observers, among others by Mr. T. Hacking, in Leicestershire, in experiments carried on for the Royal Agricultural Society of England.

Besides the work at Longleat already described, the University of Bristol has supported Mr. Ling in experiments on typical Wiltshire downland. By proper methods of intensive treatment and manuring its productivity can be doubled or trebled, though, in present economic conditions, it may not be worth the cost. In another investigation, it was found that natural untreated herbage from second grade cow pastures in the West of England, while giving an increasing percentage of protein till May, showed a decrease in June, which was nearly recovered by October. It is known in this area that milk yields tend to fall in June, and the experiments indicate that supplementary feeding may then be desirable, while, if cut for hay, West country grass should be mown as early in June as possible. Well made new hay was found to preserve most of the nutritive value, but losses in dry matter, and still more in digestibility, occurred in the stack. Experiments were to be continued on the " teart " lands of Somerset, periodically unhealthy for stock, on the nutritive value of winter herbage, on the effect of poultry on the composition of grass, on the iodine contents of herbage, and on the nitrogen metabolism of clovers.

In March, 1932, a Conference was arranged between a Sub-Committee of the Agricultural Research Council and representatives of Bristol University, consisting of Mr. Thomas Loveday, Vice-Chancellor, Mr. A. W. Ling and Dr. T. Wallace. After full discussion of the programme of grass land research, the Sub-Committee decided to recommend a grant of £200, and this recommendation was afterwards accepted by the Agricultural Research Council, and repeated for the year ending the 30th April, 1934.

Imperial Chemical Industries Agricultural Research Station

The Agricultural Research Station of Imperial Chemical Industries, Limited, at Jealott's Hill, near Bracknell, Berks., is, of course, not subsidized by the State. But, during their survey of work being done, and in view of their duty of co-ordinating that work as far as possible, it was clearly desirable that the Agricultural Research Council should accept an invitation given them to visit Jealott's Hill, to examine the programme there being carried on and compare it with those of Research Stations in receipt of national support. Two visits of Sub-Committees of the Agricultural Research Council took place in July, 1932, when the work of the Station was described by Sir Frederick Keeble and Mr. H. J. Page.

While the constitution of Imperial Chemical Industries is, of course, commercial, and the primary function of the Research Station is the investigation of the effects on soil, crops and stock of the products of the Company, the Sub-Committees found that the objects of the Station were interpreted in the broadest possible way. Much fundamental work of real theoretical importance was going on, and full information was placed at the disposal of visitors. The mental attitude and outlook of the staff were those of scientific observers, and it seemed that the only sign of the underlying commercial structure was a healthy guidance of the general direction of the work into regions where co-operation of the different sections of the staff could be secured and there was a fair probability of results of economic importance emerging. The Sub-Committees felt that this spirit of co-operation and realism would prove most beneficial to the work of the Research Station.

The problem of the intensive system of grass land management involves the study of the effects on pasture of physical and chemical treatment and of the grazing of animals, the study, that is, of the whole biotic complex. For three years the Station had been studying the effects on the production of grass of nitrogen, phosphates and lime. While there were variations from season to season, it was found that, by the use of nitrogen, the yield of dry matter could, on the average, be increased by 60 per cent. and the crude protein by 100 per cent.

The staff were also investigating the effect on herbage of grazing and cutting, and the effect of droppings as compared with that of artificial manures. Mr. Martin J. Jones was studying the results of grazing at different times in the year. Grazing in the spring prevented strong growing grasses from developing, and gave predominantly clover in the summer. Land not grazed in the spring produced rye grass and cocksfoot in quantity and clover was suppressed. Pasture grazed in March, but rested later when cocksfoot was growing, left cocksfoot predominant. Land overgrazed through the spring, when rye grass and cocksfoot were growing, and undergrazed in summer, showed chiefly Yorkshire fog, bent and thistles. It was thus shown that on the same field a farmer may produce entirely different types of herbage by varying the treatment and times of grazing.

Investigations, similar to those described above, were also being carried on upon arable crops. They may conveniently be noted here. The effects on the " lodging " of wheat, of varieties, of different dates of sowing, of spacing and of manuring were being examined. Heavier doses of nitrogen could be applied, if the spacing interval was increased and the rate of sowing decreased by 30 per cent. The wheat Swedish Chevalier stood high manuring. There was a critical date in the growth of plants at which fertilizers should be applied; a larger increase in grain and a smaller increase in straw were obtained by delaying the application of nitrogen till the middle of May. With potatoes, even when given 20 tons of farmyard manure to the acre, a mixed artificial fertilizer showed a striking improvement in the haulms, on that soil in the season of 1932. Kale was shown to be a crop which could use large quantities of nitrogen. The effects of spraying for the destruction of weeds were also being examined; for instance, the result of spraying charlock with a 5 per cent. solution of sulphuric acid in May, by killing the charlock, resulted in producing a much better yield of oats. The eradication of weeds on lawns by chemical treatment was also being studied.

Experiments on the manuring of fruit trees on standard stocks had been begun in co-operation with the East Malling Research Station.

Investigations were being made on the preservation of grass by comparing the food values obtained by silage, hay and artificial drying. The silage was of three kinds, the ordinary stack variety, the Finnish A.I.V., and that prepared by a German method, in which phosphorus pentachloride is used instead of acids to regulate fermentation. Grass was being dried by furnace gases, and the Committee was informed that attempts were being made at Billingham to design a drier which could be used by a farmer.

V. ANIMAL HEREDITY AND GENETICS

INTRODUCTION

As in the genetics of plants, the great change in our view of animal inheritance during the present century is in the application of Mendelian ideas. Till 1900, the enormous improvements seen in our flocks and herds were produced by the skilful selection for breeding of individuals showing the forms desired, on the general assumption that characters were inherited. But now, instead of regarding an individual as made up of an indiscriminate mixture of ancestral qualities, we look for signs of the inheritance of individual units, derived, it may be, from a few only of the ancestors.

The remains of domesticated animals found in the rubbish of Roman towns and of still earlier settlements show that even in those times well differentiated breeds of cattle and dogs existed. Since then the work of many generations of farmers has built up distinct races of all the different farm animals, breeds admirably fitted for life under different climatic conditions and for different purposes, for the production of milk or of beef, of mutton or wool, bacon or pork, or, amongst poultry, highly developed egg laying or a rapid development for the table.

Breeding has thus become a very highly developed art, carried out in accordance with certain definite principles, and capable in goods hands of producing not only marvellous individuals, but herds of uniform high quality.

Only within the last thirty years have any serious attempts been made to establish a science of breeding, that is of the hereditary transmission of qualities. This work, purely scientific in its aim, has necessarily been carried out with small quick breeding animals, with the fruit fly Drosophila, which will give a new generation every six weeks, and with mice, rabbits and poultry, which, though slower than Drosophila, are quick compared with cattle, and can be bred in large numbers without prohibitive expense.

This work has shown that the underlying principles of heredity are the same in all animals which have been investigated, and the field of research has already been so wide that it is certain that they apply to all domesticated animals.

In the case of those few forms in which research has gone far, it is now possible to make animals presenting any required combination of such qualities as have a known inheritance, and to predict the proportions in which these will appear in any generation.

It has been made highly probable that, as in plants, all the transmissible characters which distinguish one individual from another of the same species can be analysed into a number of units which are alternative to one another. Alternative characters, called allelomorphs, are caused to appear during development by certain extremely small things, the genes, which exist in the egg and the corresponding male sex cell the spermatozoon, and in duplicate in all the cells into which the body of the adult animal is sub-divided. These genes are handed on unaltered to subsequent generations and thus transmitted indefinitely.

Although some characters of domesticated animals, e.g., hornlessness in cattle and many colour differences, are due to a single gene, all the economically important ones, e.g., egg productivity in hens, milk production in cattle, are built up by the interaction of a large number of genes, with one another and with the internal *milieu;* that is with the remainder of the hereditary mechanism. It has also been shown that the heritable qualities of an animal are often linked together in groups, so that, if two members of a linkage group go into a cross together, they will, except in a definite proportion of cases, remain associated and will appear together either in the immediate offspring or in subsequent generations.

The number of these " linkage groups " and the numbers of individual characters included within each are very variable. In the fruit fly Drosophila, where there are four groups, the largest contains more than 180 known genes, and the smallest only some half dozen. The fowl may be expected to have some 30 groups of very different sizes, cattle perhaps rather fewer.

It has been shown that sex is inherited by the same mechanism as other qualities, and that it is linked with one group of characters. This fact is of very great importance in facilitating the analysis which is the object of genetical research.

The only commercially useful domesticated animals which have been at all extensively investigated are fowls and rabbits; and even in these cases only colour is well understood. In the case of fowls, the linkage of a pair of allelomorphic colours, gold and silver, with sex has provided a method of determining the sex of newly hatched chicks resulting from a definite cross. This cross, designed by Professor Punnett, has proved to be of considerable commercial importance. As it is frequently inconvenient to maintain pure bred stock of two different breeds, to make the cross which yields the pullets actually used in egg production, Professor Punnett has made a new breed, the "Cambar", in which at hatching all the males are easily distinguished from the females. The original numbers of this breed laid relatively few, small eggs, but its qualities in this respect have since been very greatly improved.

The more economically important problems, such as the factors which determine the inheritance of high egg production, and the sound constitution which is necessary for its continuance over a reasonable period free from disease, can only be attacked piece-meal over a long period of years. It has, for example, been stated that one or more of the important factors contributing to high fertility in hens is sex linked, that in fact it will possess an inheritance on the same plan as the colour of Cambars. The investigation of this particular problem is very much more difficult than that of colour, because many other factors affect egg laying, and the actual quality is not clear cut, but is purely quantitative. It can thus only be attacked statistically, a method involving the rearing and maintenance of very large numbers of birds.

In the case of cattle, the problems of inheritance of milk yield are at least as complex as those of egg laying by poultry, and they are far more difficult to investigate, because of the slow reproduction of cows, and the many non-inheritable factors, disease, etc., which may affect the milk yield. The well-kept herd books of the principal breeds and the records of the milk recording societies provide a great mass of data which has been extensively analysed by geneticists. The results of these investigations have so far been quite inconclusive; it is still uncertain whether there is or is not an important sex linked character involved. It is certain that many years' work, involving carefully designed experiments carried out under controlled conditions, will be necessary before our understanding of the heredity of high milk yield and other desirable characters of cattle is sufficiently advanced to exert an important influence on the practice of breeding. When they are at all adequately known, it may be expected that it will be possible to breed with considerable uniformity large numbers of animals of high quality. But long before this far distant goal is reached the information which will be derived from well designed experiments may be expected to influence the practice of breeders.

RESEARCH CENTRES IN BREEDING AND GENETICS

Small Animal Breeding Institute

The investigation of the Mendelian phenomena of inheritance in animals began with work on poultry, such as the classical experiments of Bateson and Punnett on Blue Andalusian fowls.

Questions of theoretical interest have been examined for many years by Professor R. C. Punnett, since 1912 Balfour Professor of Genetics at Cambridge, and since 1919 head of the Small Animal Breeding Institute.

Work on the genetics of small animals under Professor Punnett was first aided from the Development Fund in 1911. The work was enlarged in 1919, when Professor Punnett was appointed Director of the Institute with Mr. M. S. Pease as his assistant; and in 1923, when the National Poultry Institute scheme was launched, the Cambridge Institute was included in the scheme and received a Development Fund grant of some £2,500 for land, building and equipment estimated to cost £3,420. The remainder of the expenditure was found by the poultry industry. The Institute receives an annual maintenance grant of about £900.

The Animal Diseases and Nutrition and Breeding Committees of the Agricultural Research Council visited this Institute in February, 1932. Professor Punnett was then carrying on research in (1) fecundity, (2) sex linkage in fowls (3) sex linkage in ducks and, (4) inheritance of egg colouring. While an American investigator, Professor Raymond Pearl, had stated that fecundity was sex linked, Professor Punnett could find no evidence to support that conclusion. A series of linkage experiments in connection with fecundity indicated no linkage between the sex-linked factors for light-shank and any fecundity factor. Sex-linked chicks are now widely advertised, and one firm alone has increased the number of sex-linked eggs placed in its incubators from about 37,000 in 1929 to 817,000 in 1932.

Incidentally, results of much practical importance have emerged. As stated above, a breed, which has been named the Cambar, has been developed to show at an early stage a distinction between the sexes from down markings. Mr. M. S. Pease is improving by selective breeding and suitable crosses the productivity and egg size of the Cambar breed at the Animal Nutrition Institute. Male runner ducks are a loss to the breeder, and as it is desirable to be able to distinguish the sexes in them too at an early age, investigations parallel to those which produced the Cambar are now in progress.

Work on rabbits at the Cambridge Institute has been directed mainly to a study of the genetics of coat colour, size and pattern of coat.

Northern Poultry Breeding Station, Reaseheath, Cheshire

Problems of direct interest to the poultry breeder, especially in Lancashire and Cheshire, have been studied at the Northern Poultry Breeding Station established at Reaseheath, near Crewe, under the National Poultry Institute scheme in 1923. The annual maintenance charge to the Development Fund is about £750 per annum. The cost of establishing the Station was about £2,600, of which three-fourths were found from the Development Fund and one-fourth by the industry. Work since 1925 had been planned to examine the belief in the benefit of inbreeding in poultry without special selection, especially the benefit of mating a cock with his daughters, as expressed particularly in its effect on such qualities as fecundity, fertility and rearability.

The result goes to discredit that belief. The productivity of such inbred birds has proved to be less than that of outbred birds, the differences, though not large, being just significant. The local poultry breeders are keenly interested, and are said to have modified their practice in the light of this work.

The Ministry of Agriculture and Fisheries asked the Agricultural Research Council to advise on the future programme of this Station. A Sub-Committee of the Agricultural Research Council, upon which Professor R. C. Punnett and Professor J. B. S. Haldane kindly consented to serve in association with the members of the Council, visited Reaseheath on the 19th July, 1932. They found the work on father-daughter crossings drawing to a close, and a plan to study cousin matings under consideration. They came to the conclusion (1) that the proposed experiments in cousin matings would have little scientific value from the point of view of genetics—the problem of fecundity needs more scientific analysis of genetic factors; (2) as regards practical poultry breeding, that to obtain definite results much larger numbers of birds than those used in the past experiments would be necessary, with a further considerable outlay on capital and running expenses.

In the course of the former work several points of interest emerged incidentally, such, for instance, as evidence about the length of life of spermatozoa within the female. The Sub-Committee felt that the staff at Reaseheath were working somewhat in isolation, and thought that these points should be followed up, in consultation with those working on similar lines at other places.

As regards the main work proposed, the Northern Sub-Committee, after considering the Council's criticisms, submitted a revised programme of work, estimated to cost £650 p.a. and not to involve any new capital expenditure. This programme was first discused with Mr. M. S. Pease, of the Cambridge Animal Nutrition Institute, who had become a member of the Northern Sub-Committee. Subsequently another Conference with representatives of the Northern Sub-Committee was held at the offices of the Council on the 2nd March, 1933. On behalf of the Agricultural Research Council, it was then explained that there was no desire to turn the energies of Reaseheath from practical to theoretical investigations, but only to secure that experiments likely to interest the poultry breeder should be so planned that definite results might be reached in a reasonable time. If the proposed further series of in-breeding experiments by means chiefly of brother-sister matings were undertaken, the result might perhaps be to produce a homozygous strain which, though quite unlikely to be of any commercial use, might be of great value as a tool for further genetical researches. Since, however, it was very doubtful whether it would be possible to create such a strain, owing to loss of vitality, the attempt was not recommended. The representatives of Reaseheath then undertook, in consultation with Professor Punnett, to reconsider their programme.

In September, 1933, a revised scheme of work was referred by the Ministry to the Agricultural Research Council. It involved three divisions. The main line of work was to consist of experiments to test the respective merits of pure and first-cross breeding; breeds would be used of whose history as much information as possible was known, not only as regards pedigree, but also in regard to such factors as hatchability, fertility and rearability. Subsidiary experiments were planned (1) on an attempt to produce a strain of poultry from a commercial breed that would stand continuous in-breeding; and (2) an investigation of infertility among White Wyandottes, with the object of discovering whether infertility is inherited or not.

On the 6th October the Sub-Committee met to discuss these proposals with the help of Professor Punnett and of Dr. H. H. Parker of the Ministry of Agriculture and Fisheries, Secretary of their Reaseheath Committee. After full consideration and suggestions of certain points to be borne in mind, the programme was approved.

Institute of Animal Genetics, Department of the University of Edinburgh

The creation of an Animal Genetics Research Institute was contemplated as part of the general scheme for the development of agricultural research framed by the Development Commissioners in 1911; but, owing to the war, no action was taken until 1920, when a scheme submitted by Edinburgh University was approved, and a University Department was started in buildings in High School Yards, with Dr. F. A. E. Crew as Director. A maintenance grant of £800 was made for the first year's work. The Department was transferred to King's Buildings in West Mains Road, and in 1926 a munificent offer from the International Education Board of New York (Rockefeller Foundation) made a large scale development possible. The International Board contributed £30,000, Lord Woolvington gave £10,000, the Empire Marketing Fund provided £10,000, and a grant of £16,000 was made from the Development Fund for the purpose of a scheme which involved the endowment of a Chair in Animal Genetics, new buildings and equipment, and the creation of an endowment fund for maintenance purposes. The University gave the site and grazing land, estimated to be of the value of £5,000. In 1931, Mr. T. B. Macaulay, who had previously assisted the Department, provided the cost of purchase of Shothead Farm, and a grant amounting to £5,000 from the Development Fund was sanctioned for farm buildings, equipment, stock and endowment. A further grant, up to a limit of £5,000, was promised conditionally on the University raising a like sum. The annual maintenance grant from the Development Fund amounts to about £3,400 p.a., to meet two-thirds of the cost of that part of the Department's general programme which can be aided from agricultural funds. A further £500 is given for investigations of importance to those engaged in the rabbit breeding and fur industries. The Institute has spent some £51,000 on land, buildings and equipment, and in 1931 had a total income of the order of £13,900; but the income from private sources has been much reduced by the financial crisis. The staff and other workers numbered 38 in 1931.

It was originally proposed that the Department should concern itself mainly with the genetics of farm animals, but Dr. Crew's wide personal interests led to an extension of work into investigations on the general problem of the determination of sex and sex reversal, on sex hormones, and on the relation between the gonads and other endocrine glands, and the bearing of such relation on senility and the whole life cycle of an animal. The work was thus brought into touch with that carried on at Cambridge by Dr. Marshall and under the Medical Research Council by Dr. A. S. Parkes and his associates, Professor E. C. Dodds and Professor L. V. Korenchevsky.

In October, 1932, a visit was paid to the Animal Breeding Department, Edinburgh, by a Sub-Committee of the Agricultural Research Council, on which, in addition to members of the Council, Professors C. Lovatt Evans, J. B. S. Haldane and R. C. Punnett served. The Sub-Committee examined the general work of the Department under the following heads:—

(1) General Genetics (Professor Crew), including research in pure genetics, cytology and the physiology of the gene, investigated in a wide range of animals, such as Drosophila, mouse, rat and poultry. The work showed many instances of sex reversal, etc.

(2) Rabbit genetics (Mr. J. N. Pickard) chiefly concerned with the improvement of the constitution of the Rex rabbit and the genetic analysis of coat colour, work of interest both theoretically and to breeders of rabbits.

(3) Physiology of Reproduction (Dr. B. P. Wiesner); work on sex hormones and other endocrine organs, especially the anterior pituitary gland, and on the conditions characterising senility in rats.

(4) Sex endocrinology of the Fowl (Dr. A. W. Greenwood); work which has been in progress for many years, involving the removal of one endocrine organ after the other, the observation of the resulting changes, and the control of these changes in part by implants of gonads and the injection of sex hormones.

(5) Live Stock Breeding (Mr. A. D. Buchanan Smith); investigation of milk yields by analysis of herd books by statistical methods.

(6) Biology of the Fleece (Mr. W. C. Miller); investigations on the inheritance of kemp, and on the parts played by endocrine organs in determining the character of hair and wool.

(7) The Imperial Bureau of Animal Genetics is attached to this Institute, acting as a clearing house for information and issuing a Bulletin and periodical lists of recent literature.

The Sub-Committee which visited Edinburgh felt that the work of the Department had grown to cover almost too wide a field. Nevertheless, the work in hand called for the assistance of a cytologist, a genetical physiologist and a statistician, and a special Sub-Committee discussed with Professor Crew in a further interview in London how these requirements could be met.

In accordance with the programme submitted in 1920, when a grant from the Development Fund was first made, Professor Crew aims at using national funds for experiments on animals of economic importance, and tries to finance work of more purely theoretic interest from private contributions. He agreed with the Sub-Committee that the organisation most efficient for research is a comparatively small permanent staff of highly qualified scientific men with an adequate number of assistants, and a junior staff of less permanent nature. One difficulty in keeping within the limits of a defined programme is that many of the visitors come with their own problems set forth and with grants to meet their expenses. Animal genetics is a recognised subject in the University curriculum, and provision has to be made for teaching by some members of the staff of the Institute. The Sub-Committee felt that this co-operation was advantageous, and agreed with Professor Crew on the subjects to be represented on the permanent staff when financial circumstances allowed.

As regards Dr. Greenwood's work on poultry, which was subsequently examined further by a member of the Council in Edinburgh, it was finally agreed that the Scottish Department of Agriculture, and through them the University, should be advised that Dr. Greenwood should be asked to collect and systematise the data already obtained relating to egg production, etc., which seemed to be of great potential value, and that further experiments on the endocrinology of the fowl should meanwhile be suspended.

The work on wool had been carried on by a grant of £800 per annum for five years from the Empire Marketing Fund, which ended at the 31st March, 1933. In order to enable Mr. Miller to continue this work until the position could be reviewed, the Agricultural Research Council made at first a temporary grant of £205 for six months. Subsequently it was found necessary to give temporary assistance for a longer period.

The Sub-Committee gave much attention to the work on the inheritance of milk yields in cattle. Herd books are inadequate material, since the standard of all the cows recorded is high, and they may be homozygous for many of the factors involved. Statistical work appears to have yielded nearly all the information which can be expected, and, as suggested by Dr. Buchanan Smith, further advance can only be made by a planned experiment on a large scale.

The view of the Sub-Committee, however, was that this experiment was not urgent, and that no considerable expenditure should, in present circumstances, be incurred on it. Nevertheless, if a scientific analysis of the factors underlying heredity in cattle is ever to be made, some such experiment as that proposed will be necessary, but the numbers of cattle used must be large, the time extensive, and consequently the cost high. Some members of the Sub-Committee, however, thought that a comparatively manageable experiment on the crossing of high and low yielding strains, followed by a reciprocal cross, would suffice to answer the important question whether the milk-yielding factor is sex-linked or not, and that this experiment should be made when the necessary funds were available.

VI. ANIMAL PHYSIOLOGY AND NUTRITION

INTRODUCTION

The subjects of animal heredity and genetics are closely connected with those of the physiology of reproduction and of animal physiology in general. Again, many of the crops dealt with in Chapter IV are grown as food for animals. Hence the study of plants leads also to those of animal nutrition and animal physiology, the sciences which underlie that important part of practical farming known as animal husbandry.

On the other hand, a disturbance in the healthy physiological processes of an animal causes disease. Moreover, it is now known that many diseases are due to faults of nutrition, and thus a close liaison exists, or should exist, between the study of disease and the general study of nutrition. As medical students (and indeed everyone) should be taught the physiology of the human body, including dietetics, as a guide to methods of maintaining it in health, so agricultural and veterinary students should include in their work animal physiology and animal nutrition.

Down to the middle of the last century the farmer in feeding his stock was guided by tradition modified by his personal experience and judgment. The results, owing to local conditions, might vary from district to district, but we know that exceptional individuals, with intuitive wisdom and skill, attained to great success without the aid of scientific knowledge. Average results, however, provided the measure for contemporary expectations, and that these could be bettered as a whole by a search for more systematised and more quantitative knowledge was not then admitted or even realised by the average raisers of stock.

In the middle years of the century, however, largely owing to the initiative and pioneer work of Justus von Liebig, scientific studies of animal nutrition began, and quantitative data concerning nutritional needs rapidly accumulated. To the contemporary generation of farmers this growing knowledge made little appeal, but to their immediate successors its value became more obvious, and many enlightened stock-raisers encouraged scientific studies, helped their endowment, and applied the results in practice. Thus, before the end of the century a large body of sound quantitative knowledge had accumulated, and the popularity of the standard text books which summarised it showed that it was valued in practice. That knowledge comprised an adequate understanding of the total energy needs of this or that species of farm animal and their variation with the purpose for which the species was bred. It had made clear the special functions of the main organic constituents of food, the proteins, fats and carbohydrates, and indicated the right ratio in which these should be supplied for the attainments of a given desired result. It called attention to the importance of certain minerals in the diet. The literature on the subject at this time supplied also abundant data concerning the digestibility of diverse rations, thus demonstrating the degree to which their constituents were actually available for the purposes of the body.

Knowledge in categories like these, extending to many details, but not of course complete in all, was available thirty years ago. Early in this century, however, knowledge belonging to a different category began to come into prominence, and the growth of this knowledge has made it clear that the essentials of normal nutrition are more numerous and more complex than was thought. It had, indeed, been earlier realised in practice that rations quantitatively adequate according to accepted scientific standards might on occasions fail to secure nutritional success. Later carefully controlled experiments have made clear the reason for this. It has been shown that, in addition to such fundamental needs as fuel and building materials, which had previously monopolised the attention of experts, the animal body requires a supply of subtler nutrients, each with some special function in support of health, growth and fertility. Some are organic in nature, comprising in particular a group of vitamins; others are mineral elements with functions no less essential. These accessory constituents of an adequate diet are required in characteristically small amounts, but that some of them are essential for the well-being of every animal is sure. It may be said, indeed, that the centre of interest in research has shifted from the quantitative to the qualitative aspects of nutrition, not because the former are less important, but because the latter are less understood. While inadequacy in respect of any one of the accessory factors just mentioned may lead to malnutrition, if the deficiency be great enough, it may result in what is to-day known as a " deficiency disease ".

Urgency in the demands for this one or that among the substances in question varies from species to species, so that information obtained in the study of small laboratory animals cannot be directly applied to those of the farm. The needs of each species call, indeed, for special study.

Deficiencies in the vitamin supply seem for various reasons less likely to occur in the diet of farm animals (if pigs and poultry be excepted) than in that of some other species or in human diet. Nevertheless, carefully conducted experiments are now showing that significant degrees of malnutrition can be traced to a relative lack of certain vitamins even in farm stock. In their case, however, diseases due to mineral deficiency are more prominent and have been more studied. Some of them have attracted special attention, such for instance as styfsiekta in cattle, rickets and osteoporosis in cattle, sheep and pigs, and primary anaemias of various kinds. In such diseases a proper supply of the mineral lacking in the food will generally remove the symptoms, but their etiology is not in every case fully clear, and even the best known among them need further study.

That there are subtle aspects of nutrition, which call for much more research before they are understood, will not be denied by those who remember that on one of two adjacent and apparently similar pastures animals may thrive and on the other fail.

With recognition of the fact that a single deficiency in diet may, if complete enough, lead to actual disease, it becomes logical to enquire whether a similar deficiency, when less complete, may not lead to significant degrees of subnormal health. It is the conviction of many who rely upon first-hand evidence that this is frequently the case. Lowered vitality leading to lessened capacity for growth, work or re-production, for which till lately a cause would have been sought in quite different directions, may well prove to be due to a dietetic error, small in magnitude, but important in kind.

It need hardly be said that a factor which limits good health may be a limiting factor for every kind of production. A striking example of this was provided by certain observations in South Africa. Styfsiekta prevalent in cows was cured by adding phosphates to the phosphorus-deficient food. With the disappearance of the malnutrition, the milk yield increased by 30 per cent., and an increase in the growth of young cattle involved all the tissues of the body and not the skeleton alone. Lack of phosphorus had previously been a limiting factor in the utilisation of food as a whole. So might be a deficiency in any other essential constituent of food, however small the quantitative demand for it. Evidence that general failure may follow upon a minor deficiency, acting as a limiting factor, has been obtained in experimental pig-feeding. In the special case of poultry farming the importance of minor adjustments in the food is fast becoming recognised, not only for good growth and condition, but also for egg production and hatchability.

Knowledge, however, of all the essential constituents of a good dietary is in itself not enough. Ideal nutrition calls for an ideal physiological balance among them. To reach the ideal is the final goal of all nutritional research, but the goal is yet distant.

Another question arises. Does malnutrition, even of lesser degree, lead to increased susceptibility to infectious diseases? A certain answer can only be given by research; but again there are many whose first-hand experience has convinced them that it does. The incidence of disease in farm animals is still notoriously high, in spite of the great advances that have been made in its control by sanitation and preventive inoculations. It involves much economic loss. Yet such loss is less from the relatively small number of animals which die of disease than from the much larger number, which, owing to impaired health, fall far short of the productive capacity proper to their powers.

In experiments made to trace the cause of a nutritional failure, or to measure the importance of a particular variation in a diet, two groups of animals need to be fed; a control group and an experimental. The only difference in the food of these must be the presence or absence of the factor under study. As the value of such an experiment is greatly increased when the results can be submitted to statistical analysis, the number of animals employed must be as large as possible. It follows that such studies call for considerable expenditure. We know enough to-day about animal nutrition to realise that we need to know much more, and to feel sure that expenditure upon research is a profitable investment.

PRESENT RESEARCH.

The Rowett Research Institute, Aberdeen

In the original scheme for the promotion of agricultural research, framed by the Development Commissioners in 1911, it was contemplated that two Institutes for research in Animal Nutrition would be required, one at Cambridge and probably one in Scotland. In 1914 work on this subject was begun in Marischal College, Aberdeen, but the establishment of an Institute was delayed by the absence on active service throughout the war of Dr. J. B. Orr, who was appointed Director. In 1920, when the late Dr. John Q. Rowett provided a site at Bucksburn, near Aberdeen, and contributed the sum of £10,000, a capital grant of £20,000 on the £ for £ basis was offered from the Development Fund, for the cost of establishing the Institute, which was opened in 1922. In 1925-26 a basic grant of £29,100 and a £ for £

grant of £13,000 from the Development Fund were sanctioned in aid of the cost of creating and endowing the Duthie Experimental Farm of about 1,000 acres, to be attached to the Institute. For this purpose Mr. J. Duthie Webster made a gift of £12,000. The Institute is managed by a Governing Body, consisting of ten members, five appointed by the University of Aberdeen, and five by the North of Scotland College of Agriculture. Attached to the Institute are the Reid Library, established in 1923, endowed by gifts from Dr. Walter A. Reid amounting to £10,000 in all, and the Imperial Bureau of Animal Nutrition, established in 1929 by means of grants from the Council of the Imperial Agricultural Bureaux. A residential hall, costing about £20,000, which was raised by private subscriptions, has been added recently and named Strathcona House. The Institute receives a Development Fund maintenance grant, made to the Department of Agriculture for Scotland, of about £12,000 a year. The farm is self-supporting.

Two visits have been paid by Sub-Committees of the Agricultural Research Council to the Rowett Institute, on the 14th June, 1932, and on the 5th April, 1933. On the second occasion members of the Council had the valued assistance of Professor H. S. Raper of Manchester.

Both Sub-Committees were impressed with the general scheme of organisation of the Institute, with the arrangements for efficient team work, and for keeping continually in mind the bearing of the work on the economics of practical farming. Dr. Orr, the Director, sets as his ideal a small, first-rate and highly trained permanent staff, helped by additional temporary staff. And, as a matter of fact, there is a permanent staff at the Rowett Institute of about thirteen, but a large number of men and women, holding temporary appointments or research grants, and voluntary workers are also attached. This constitution should be contrasted with that of most Research Institutes, where the greater part of the staff is permanent, many of them being established on the graded system. The Animal Diseases and Nutrition Committees of the Agricultural Research Council have expressed a preference for the kind of constitution illustrated by the Rowett Institute, provided that continuous supervision is exercised by the Director and permanent staff.

The policy of the Rowett Institute is determined and adjusted to changing circumstances by monthly meetings of the permanent staff. At these meetings the financial accounts are considered before the scientific research programme. The experimental Duthie farm, and the sheep farm of Garrochoran, selected deliberately for the poor quality of the pasture, are used to try out the large scale and economic effects of laboratory results. This often throws back to the laboratory the problem in another form, or even a new problem. At all events research workers are kept in close touch with practical problems in their economic aspect, and have to correlate their own work with the general aims of the Institute. All the data obtained in every experiment are recorded and filed in the office of the Institute. These records at some future date may give the solution of a problem not envisaged at the time of experiment.

The original programme of the Institute was planned in close consultation with the late Professor T. B. Wood, and, during his life, was dovetailed with the work at the Animal Nutrition Institute at Cambridge, of which he was Director. Speaking broadly, Cambridge undertook work on the protein, fat and carbohydrate, and Aberdeen on the mineral and vitamin requirements of animals.

One result which emerged at an early stage and has influenced all subsequent work is the great importance of diet in the health of animals, and conversely the effect of health on the absorption of nutriment. If its diet is chemically incomplete, an animal is not likely to be well, but when well an animal can make complete use of a considerable variety of food. As far as cattle are concerned, mineral requirements seem to call for attention more than vitamins, an adequate supply of which can usually be assumed.

The Physiology Department was working on the respiratory exchange in fowls and on a study of the urine and blood in relation to the low respiratory quotient found in other animals; on carbohydrate absorption and metabolism in ruminants and other animals; on the influence of vitamin D on calcium and phosphate metabolism; on the movements of the alimentary canal; and, by means of experiments on sheep, goats and rats, on the relation between nutrition and resistance to disease. The immunological work is carried on in close association with the Bacteriology Department of Edinburgh University under Professor T. J. Mackie.

Work is also being done by Mr. W. Godden and others on the composition of the blood of cows through an annual cycle. The cows used in this experiment are now divided into two groups, fed on different diets, with the object of studying the possible effect of diet on the composition of milk and the correlation of milk composition with that of blood. The blood of breeding ewes on an adequate diet and on one deficient in calcium is being compared. A beginning has been made in research into the chlorine requirements of farm animals and, in conjunction with Professor L. S. P. Davidson and the local Public Health Department, dietary surveys are being made of the poorer population of Aberdeen. The surveys show that only a bare minimum of iron is being received, and that many of the women are anaemic. Incidentally the results seem to have a bearing on iron deficiency in farm animals. The Department is assaying dried milk mixed with a vitamin preparation for vitamins A and D, in co-operation with the Hannah Dairy Research Institute.

The farms are also concerned in much of this work. They are under the general direction of Mr. A. Crichton, and deal with cattle, sheep, pigs and poultry. Each section keeps independent accounts and is expected to pay its way. This fact, and the testing of laboratory results in farm conditions, give the Institute a high reputation among farmers. Recent experiments at the Institute and the farms include the dieting of dairy cows; the effect of supplementary food on sheep fed on the mineral-deficient pastures of Garrochoran; the effect of diet on the immunity reactions of wether hoggs, and on the susceptibility to *Haemonchus* of sheep turned out on infected ground, an experiment made in collaboration with Dr. D. Robertson of Aberdeen University; the influence of an adequate diet on the resistance of lambs to adverse conditions as compared with one deficient in calcium and vitamin D; cystine in wool in relation to the food ration; alternatives to fish meal in pig-feeding, carried on in conjunction with Harper Adams College and Cambridge; and the dietetic value and cost of various forms of food for poultry.

The Agricultural Research Council have learned with interest of the recent appointment to the temporary staff of the Institute of a veterinary surgeon, primarily for work on contagious abortion. It would appear that the services of a veterinary surgeon should be of considerable value in helping to advance knowledge of the relation between nutrition and disease.

The Cambridge Institute for Animal Nutrition

The Institute for Animal Nutrition at Cambridge was largely the creation of the late Professor T. B. Wood. Since his death, it has been under the direction of Dr. F. H. A. Marshall, the distinguished physiologist, whose term of office ended on the 31st December, 1933. The Institute was formed under the 1911 scheme of the Development Commissioners and was attached to the School of Agriculture. The cost of its buildings and equipment was borne out of a Development Fund grant of £18,000 made for the provision of a second section of the School of Agriculture. A sum of

£20,000 had been raised privately to cover the cost of the first section. In 1924 a further grant from the Development Fund of £21,500 was sanctioned, mainly to provide accommodation for the Plant Breeding and Animal Nutrition Institutes. In 1930-31 a grant of £50,000, spread over five years, was promised from the Development Fund with a similar grant from the Empire Marketing Fund. These grants were made to help meet the conditions of the munificent gift of the Rockefeller Foundation for the development of the physical and biological sciences at Cambridge, £162,900 of which was attributable to the sciences bearing on Agriculture, the balance being raised by the University.

Facilities for that part of the work of the Animal Nutrition Institute which needs space are provided on the University farms. In 1922 a grant of £7,000 and a loan of £3,000 (convertible into a grant on the £ for £ principle) was provided from the Development Fund for the purchase of the freehold of the farms, and in connection with the Rockefeller scheme the University undertook to raise £16,000 for farm buildings and equipment. The Empire Marketing Board also made a maximum capital grant of £5,000 for work on the physiology and growth of farm animals, and a capital grant of £890 for poultry nutritional research. The Institute receives from the Ministry of Agriculture and Fisheries an annual Development Fund maintenance grant of about £13,000. For the five years from July, 1927, it was offered by the Empire Marketing Board a grant of £400 per annum for the researches on the physiology and growth of farm animals referred to above, and from April, 1929, a grant of £1,870 spread over five years for nutritional investigations on poultry.

The Institute was visited first by members of the Animal Diseases and Animal Nutrition Committees of the Council on the 16th February, 1932, and later the work was examined more intensively by a Sub-Committee, which was at the Institute on the 20th and 21st February, 1933. Interviews subsequently took place in London with the Director and Professor F. L. Engledow, Drapers Professor of Agriculture.

The Institute at present consists of several sections. The physiology of growth and reproduction is studied by Dr. Marshall, Dr. J. Hammond, Dr. A. Walton and other colleagues. Dr. Marshall's own researches on sex hormones in animals are too well-known to need more than a passing reference His recent experiments with Professor T. H. Bissonette of Connecticut on the effect on the fertility of ferrets of subjecting them in the non-breeding season to strong electric light during the evening are of much interest, and attempts are now being made to test the results on farm animals. Dr. Hammond, in addition to his work on reproduction in the mare, and fertility and growth in rabbits, is giving attention to the breeding of types of pigs suitable for bacon and pork production, and to the development of fat and lean in the best proportions in the bodies of sheep and other farm stock. Dr. Walton is chiefly engaged on a study of fertility in the rabbit and fowl, and of the problems of artificial insemination.

Dr. H. E. Woodman and others in the chemical section are still engaged on their well-known study of pasture grass and other fodder crops, and the influence on their composition and qualities of early and frequent cutting, different manurial treatment and different intensities of grazing. They have been examining the use of grass, whether dried or in the form of silage, for winter feeding. Mr. F. W. Foreman carries the study of chemical composition a stage further, and investigates the exact chemical nature of the solids and also of the juices expressed from such plants as white clover and rye grass. He finds these juices to be rich in a carbohydrate, which he suggests is a laevulin; it yields hexoses on hydrolysis and is of high nutritive value. From the woody residue pentoses can be extracted readily, but these, Mr. Foreman points out, are not used by the animal.

Dr. T. Deighton deals with calorimetric measurements—hitherto made on larger animals such as pigs, but now to be extended to fowls. Mr. G. Dunlop is experimenting on pigs, examining such factors as the influence of vitamin D on the mineral balance, especially the calcium/phosphorus ratio. Poultry nutritional problems are being investigated by Mr. E. T. Halnan with the assistance of Dr. E. M. Cruickshank; their researches on fat metabolism promise results of much importance. Mr. Pease is building up a commercial strain of sex-linked Cambar fowls. The original crosses were made under Professor R. C. Punnett, in the Small Animal Breeding Institute, as explained elsewhere in this Report.

The Sub-Committee which examined the work for the Council, like the Animal Diseases and Nutrition Committees at an earlier date, were favourably impressed by the importance of much of the work and by the keenness and interest displayed by the individual workers, but they remarked on a certain lack of co-operation between them, and on the consequent want of a uniform aim. They thought that the work of the Institute, which covered so wide a field, not only of research on animal nutrition, but also on reproduction and growth in farm animals, should be more closely knit together.

The result of the examination of the work being done at the Animal Pathology and Animal Nutrition Institutes at

Cambridge led the Agricultural Research Council to think that the time had come for a general review of the agricultural Institutes at Cambridge, of their relations with the University and with its departments. After consultation with the Ministry of Agriculture and Fisheries, therefore, the Council approached the Vice-Chancellor, suggesting that such an enquiry should be undertaken by the University.

In response to this suggestion, the University appointed a Syndicate, which carried out a long and exhaustive enquiry into the subject, and made a Report, published in the Cambridge University Reporter of the 16th May, 1933, and 6th June, 1933, and later adopted by the University. The chief changes thus initiated are as follows.

The Agricultural Research Institutes are to work under the control of a Central Committee, of which the Drapers Professor of Agriculture is to be Chairman, but on which no member of the staff of an Institute can serve. The Central Committee is to submit to the Ministry of Agriculture and Fisheries and to the Agricultural Research Council estimates, programmes of research and annual reports of the Institutes; to foster co-operation among the different Research Institutes and the scientific departments of the University; " to recommend the termination of an unprofitable or otherwise unsatisfactory inquiry "; and to decide whether an Institute shall be under the immediate control of a Director or of a Committee of Management.

Directors and members of the staffs of Institutes and of advisory services shall undertake as part of their normal duties such advanced teaching in their subject as the Faculty Board of the University may request and the Central Committee approve. They may also, with consent of the Central Committee and of the Ministry, undertake other regular courses of instruction in the University.

The Agricultural Research Council consider that this Report marks an important improvement in the organisation of the Cambridge Research Institutes. They also welcome the provision whereby research staffs can be called on to do teaching in their special subjects. They consider that most research workers benefit by doing some teaching, and teachers by doing research.

VII. DISEASES OF ANIMALS

INTRODUCTION

At an early stage in its history, the Agricultural Research Council came to the conclusion that research work on the diseases of animals was one of the most important and the most urgent of the subjects coming into its purview.

Live stock and live stock products are by far the most important part of the output of British agriculture, amounting in value in the agricultural year 1930-31 to £138,660,000 in England and Wales and to £31,433,000 in Scotland, or nearly 73 per cent. of the whole agricultural output. The toll taken by disease on our flocks and herds involves a direct loss of some millions of pounds annually, while the indirect loss is incalculable.

Cattle suffer continually from numerous infective enzootic diseases (such as tuberculosis, contagious abortion, mastitis and Johne's disease), and from epizootics which only occur intermittently, but nevertheless are a serious scourge. Sheep and pigs are also liable to similar inroads on their health, causing a high mortality, while the rapidly increasing poultry stock of the country is subject to many causes of loss and deterioration. Moreover some of these diseases are dangerous to human life. Children are especially susceptible to the bovine type of tubercle bacillus, while there is a connection between contagious abortion in cattle and undulant fever in man, and between certain forms of streptococcal mastitis and septic sore throat.

To meet this perpetual loss and potential danger, measures both administrative and investigational are needed. The Ministry of Agriculture and Fisheries is responsible for the control of scheduled animal diseases in Great Britain. The Ministry has a staff of veterinary inspectors stationed about the country; the Local Authorities have their own Veterinary staffs; and to some of the Agricultural Colleges and Research Institutes Veterinary Advisers are attached, who also undertake local investigations. The most important centres of research in England at present are the Ministry's Laboratory at New Haw, Weybridge, the Institute for Animal Pathology at Cambridge, and the Research Institute in Animal Pathology at the Royal Veterinary College, London. In Scotland valuable work, on sheep diseases in particular, is being developed at the Moredun Institute of the Animal Diseases Research Association.

In consequence of the connection between animal and human diseases, in 1932 the Agricultural Research Council and the Medical Research Council established joint Committees on Tuberculosis and Thyroid Disease, and the Agricultural Research Council arranged for representatives of human medicine to serve on several of their Committees.

RESEARCH IN GREAT BRITAIN DURING THE EARLY PART OF THE PRESENT CENTURY

Until the last decade, research into the causes and prevention of diseases of animals had not been carried on as actively in the British Isles as in many other countries, because funds and sufficiently equipped laboratories were not available, though a certain amount of work was being done at the Veterinary Colleges and Schools. During the last fourteen years some amends have been made for this defect. The laboratory of the Ministry of Agriculture at New Haw, Weybridge, was opened in 1917, the Research Institute at the Royal Veterinary College in 1923, the Cambridge Institute of Animal Pathology in 1923, and the Institute of the Animal Diseases Research Association of Scotland at Moredun in 1926. The Committee for Research into Foot and Mouth Disease was appointed in 1924, and a Station at Pirbright, with accommodation for keeping cattle in isolation, was taken over by the Committee.

In spite of the want of facilities, during the first quarter of the century a considerable amount of research work in Veterinary Science was carried out, mainly at the Royal Veterinary College in London, the Royal (Dick) Veterinary College in Edinburgh, the former Laboratory of the Board of Agriculture at Sudbury, and in Laboratories devoted chiefly to Human Medicine. Some of the more important investigations published during this period may be mentioned here.

A series of papers(1)* appeared between 1896 and 1904 describing work at the Royal Veterinary College on Glanders, including the first use of the agglutination reaction with *Bacillus mallei* and investigations with mallein for diagnosis. As is well known, glanders has now been eradicated from this country by the slaughter of all horses in which the disease was diagnosed.

Intestinal coccidiosis of lambs was described(2) and investigated in 1896. The increasing importance of virus diseases gives interest to the fact that African Horse-sickness (3) was first shown to be due to a filtrable virus at the Royal Veterinary College in 1900, and further work was done with the infective agent in 1901. If pleuro-pneumonia of cattle is excepted, this was the second disease of animals for which a true filter-passing virus was established, foot and mouth disease having been the first.

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* The numbers are concerned with the references given on pp. 154–156.

The Report in 1906 of the Departmental Committee on Louping Ill and Braxy (1901) makes clear the great difficulties under which work on the pathology of these diseases was carried out at that time. The diagnosis was confused with that of other causes of mortality in sheep, and the kinds of bacteria found in carcasses could not be clearly distinguished. Immunisation by administration of living cultures through the mouth was advocated for both diseases. These conclusions were perhaps to some extent justified for Braxy, but in the case of Louping Ill they are hard to reconcile with modern knowledge.

The Royal Commission on Tuberculosis (1901) will be referred to later. In 1905 a Departmental Committee was appointed on Epizootic (i.e., Contagious) Abortion of Cattle. It reported in 1909-1910 that the disease was widely spread in this country, and agglutination and complement fixation tests of the blood for diagnosis were introduced(4). The results of further investigations(5, 6) were published in 1912-3 on the pathology of the disease and the means by which it was transmitted. In 1914 experiments on the possibility of procuring immunity(7) with living and dead vaccines were carried out. Between 1913 and 1924, attempts at eradication were made with considerable success (8,9). In 1914 the unexpected observation (10) was made at the Royal Army Medical College that the milk and blood serum of cows in London would agglutinate the micro-organism of Malta (Undulant) fever, whose relationship with the causal bacterium of contagious abortion was not suspected till 1918.

The first recognised case of Johne's disease (11) of cattle in Great Britain was recorded in 1907. A method of cultivating the causal bacillus (12, 13) was first described in 1912 and experiments with "johnin" as a diagnostic agent were also reported. Other experiments with johnin(14) were published in 1916. In 1911 Johne's disease was diagnosed in sheep(15), and in 1916 experiments(16) on the transmission of this infection from cattle to cattle and attempts to infect sheep, goats and other animals were published, but the identity of the natural diseases in bovines and ovines has never been established. A paper on the detailed histology of the lesions of Johne's disease(17) appeared in 1918.

The methods which had been advocated for conferring immunity against Tuberculosis by the inoculation of living bacilli(18) of the human and avian types were examined experimentally in 1913, but not found to be of practical value. A series of experiments was carried out at the Royal Veterinary College in 1914 to compare the different methods of testing cattle with tuberculin(19), by subcutaneous, intracutaneous and conjunctival inoculation. The method of eliminating contaminating bacteria in human sputum with antiformin before testing it for tubercle bacilli by the inoculation of guinea-pigs was applied in 1915 to the treatment of the dung of cattle(20) before the application of a similar test. The occurrence of Red-water in cattle (21, 22) in this country was reported and observations on the species of piroplasma in the blood were published in 1911-4.

The cause of both Abortion in mares and Joint-ill in foals in Great Britain was referred in 1917 to *Bacillus abortivo-equinus,* and further investigations (23) of joint-ill were made in 1919.

Two Departmental Committees (1896, 1910) investigated Swine Fever chiefly with a view to improving the diagnosis and advising on administrative measures. The results of an experimental investigation(24) were published in 1917 and the value of the inoculation with anti-serum, with or without virus given at the same time as a protective measure, was examined without establishing any great advantage from these procedures.

In 1918 a series of experiments was made to examine current views as to the cause of Scrapie in sheep(25), and in 1916-8 the transmission of Louping Ill by sheep ticks(26) was enquired into experimentally with ambiguous results.

In the Dominions and India, where new problems in Agriculture have forced themselves on the notice of the Governments, Veterinary research has received considerable support, and the establishment of the Institute at Onderstepoort under the direction of Sir Arnold Theiler has notably advanced veterinary medicine, especially regarding diseases met with in South Africa.

The essentially close connection between animal and human diseases has long been recognised in the British Isles, but their study by veterinary and human pathologists together has been practised comparatively seldom in England, whereas on the Continent of Europe a number of distinguished scientists have been almost equally noted for their researches in the diseases of man and of animals. The Royal Commission on Tuberculosis (1901) and the Foot and Mouth Disease Research Committee have included members of both professions.

RECENT RESEARCH IN THIS COUNTRY

Further advances in the field of animal pathology have been made by British workers of more recent years, but a very large amount of work still remains to be done.

In the following review only the research carried out in this country has been referred to and the list of papers quoted is by no means complete, but it includes those giving full bibliographies.

Tuberculosis

Tuberculosis, with special reference to the relations between human and bovine forms of the disease, was studied by the Royal Commission on Tuberculosis appointed in 1901, which reported in 1907 and 1911-13, with the result that the differences in cultural and disease-producing characteristics between the two types of the tubercle bacillus and the resistance of bovines and rabbits to the human type were confirmed. The susceptibility of man and the guinea-pig to both types was established, and the observation that adult human pulmonary consumption is almost always due to the human type was endorsed. Tuberculosis in other animals was also investigated.

Research begun under the Royal Commission on the bacteriology and pathology of this disease in man (27) and animals (28, 29) has since been continued at the Field Laboratories and the Institute of Animal Pathology at Cambridge (with the assistance of the Medical Research Council as well as from the Development and Empire Marketing Funds) and elsewhere. Amongst other conclusions it has been found that the bovine type takes a large share in producing tuberculosis in children.

Investigations have also dealt with the Avian type of tubercle bacillus—the third type affecting warm-blooded animals, which has definite distinctive characters and often attacks poultry and sometimes mammals.

Pigs have been shown to suffer from naturally acquired infections with any one of the three types, but severe infections are usually due to the bovine bacillus. In pigs the route of entry is probably always by way of the alimentary canal.

The bovine type of bacillus is known to be highly virulent for man, and the fact that its manifestations in human beings are chiefly confined to sites other than the lungs is due to its entrance into the body with food. The early stages of infection are almost exclusively found in children, because of the greater susceptibility at this age and the relatively large amount of milk which they consume.

Tuberculosis of the horse is not very rare; the bacilli isolated have unusual characters, but are probably derived from the bovine type. Sheep are rarely infected in this country and goats very rarely, the bovine type being usually responsible. Cats and dogs are not uncommonly attacked, the former by bovine, the latter by either the human or bovine type. Monkeys, like man, may be infected with either type.

There is urgent need for further research on the widespread tuberculosis of cattle and no less for action to be taken in accordance with the facts already known.

In herds of cattle the percentage affected is on the average not less than 40, and at least 5 per thousand of milch cows have been shown to give infected milk. The disease is spread amongst cattle from the lungs in coughing and by infected dung, especially in crowded and dirty cowsheds, and also by the milk. Tubercle bacilli survive a long time in dust, in dung and on the earth and grass of pastures, but how far the infection of pastures is a serious means of spread is not known and is at present the subject of experimental enquiry.

Several methods have been introduced for rendering calves immune to tuberculosis. Vaccines made with living or dead tubercle bacilli have frequently been advocated, but usually have been found to give but a slight degree of protection or one which is only temporary, and some have proved actively harmful or lead to infection of the milk. The attenuated culture introduced by Calmette and Guérin for this purpose in 1924, and known as BCG, has been used extensively in France and some other countries, but its value in the field is by no means generally accepted. Its effect under carefully controlled conditions is at present being tested at Cambridge (30). The chief objections which have been made to its use are the short time during which the immunity lasts, the positive reaction to tuberculin which may be given by inoculated animals, and the uncertainty whether this strain of bacillus may regain virulence. These reputed drawbacks are now being very carefully examined.

The use of dead vaccines has not been sufficiently tested, and is now the subject of investigation, which should be continued with a still wider scope. So far there is no satisfactory evidence of their practical value, though they have long been known to give a degree of temporary protection against infections with strains of the tubercle bacillus of only slight activity.

It has been shown that a dairy herd can be freed from tuberculosis by systematic and regular testing with tuberculin of all the cows in it, and of those to be admitted to it, and the exclusion and segregation or slaughter of all positive reactors together with reasonable cleanliness and hygienic measures. This programme has been successfully carried out on a very large scale in the United States and Canada and in a number of herds in this country. A scheme of eradication, with some assistance to the farmers by means of gratuitous testing and advice, has recently been tried in Scotland by the Hannah Dairy Research Institute with very encouraging results.(31)

It has been found that if the calves of tuberculous cows are isolated from their mothers at birth, they can be reared as a healthy herd, with proper attention to their diet (32).

The technique of tuberculin testing has been investigated and improved of late years. Active enquiry is also going on into better methods of preparing tuberculin,(33) especially by growing the bacillus on simpler culture media and the avoidance of prolonged heating. There is great need for a recognised standard of tuberculin, such as has been established for use in human medicine.

The fate of tuberculous animals excluded from a tuberculin tested herd is a serious blot at the present time on schemes of eradication, since a positive reactor may after removal to another herd continue to disseminate infection in milk and in other ways. Unfortunately the high incidence of the disease in this country makes the immediate slaughter of all reactors impossible. Veterinary inspection and the slaughter of animals showing clinical signs of disease improves to some extent the safety of the milk supply, but does very little to diminish the number of tuberculous animals.

Johne's Disease

Johne's disease of cattle was first described in Denmark in 1895. It is a chronic inflammatory disease of the intestines due to *Bacillus paratuberculosis* and leading to diarrhoea, wasting and death. It is very prevalent in some parts of England and appears to be increasing. Like the tubercle bacillus, which it resembles, Johne's bacillus is " acid fast ", that is, it contains constituents which give it the property of retaining Ziehl-Nielsen's stain when treated with acids. It can only be cultivated on special media which usually contain extracts of some other acid-fast bacillus, such as the timothy grass bacillus (*B. phlei*). Sheep are sometimes affected naturally by a similar disease due to the same or a related bacillus. It has not been found possible to transmit Johne's disease to small laboratory animals. Johne's disease is spread by contamination of water and pastures with the bacilli excreted in the faeces. Diagnosis is made by examining for the bacilli the faeces or a small piece of the mucous membrane taken from the lower bowel. A product, "johnin" (34), like tuberculin, is made from cultures of the bacillus by heating and concentrating, and this re-agent, when inoculated intradermally into cattle, causes a specific reaction not unlike that produced in tuberculous animals by tuberculin. Research on johnin is at present in progress. It is claimed that it can be used like tuberculin to detect and eliminate infected animals from a herd.

Contagious Abortion

Contagious abortion of cattle shares with tuberculosis and Johne's disease a place amongst the most important and serious diseases of cattle in this country. It is enzootic and commonly affects 30 to 40 per cent. of the cows in dairy herds.(35) Such a high incidence has been proved by testing the agglutination reactions of the blood and by showing the presence of the causal bacterium, *Brucella abortus,* in the milk by inoculating guinea pigs. This bacterium, which was found by Bang in 1897 to be the cause of the disease, can only with difficulty be distinguished from *Br. melitensis,* which was shown in 1907 to infect goats in the Mediterranean area. Both these micro-organisms may cause undulant fever in man,(36) *Br. melitensis* much more readily. The infection of cattle is very persistent and may cause the same animal to abort repeatedly, but sometimes later pregnancies terminate normally or the animal may become sterile. The disease spreads readily, chiefly by means of the uterine discharges after abortion or calving. The bacteria are also present in the udder and the milk; young calves usually become infected in this way, but as a rule recover.

It has been found, especially in the United States, that the disease can be eradicated from a herd by the segregation of animals which have been shown to be infected by testing their blood. The cost and efficacy of this method are at present being investigated in a number of herds in Great Britain. Inoculation of uninfected non-pregnant cows and heifers with a vaccine consisting of a living culture of *Br. abortus*(37) is often used as a means of preventing abortion. If the vaccinated animal passes through the early stage of the resulting infection before or soon after the beginning of pregnancy, abortion may be avoided. Nevertheless infection has resulted from the vaccination and may remain active or latent for an indefinite period, and the bacilli may be present in the milk. This procedure is said to diminish the frequency of abortion, if it is already prevalent in a herd, but the opinions as to its practical value are not unanimous, and no doubt the living vaccine entails some risk of further spread of the disease and hinders eradication measures. Further research on the course and sources of infection in this disease and a renewed search for an efficient innocuous preventive vaccine are much needed and are in progress.

Br. abortus is known to occur in local infections in the horse, especially in fistulous withers.(38)

Mastitis

Several forms of Mastitis occur in dairy herds, including some very acute and even fatal cases. But the much commoner forms are chronic and recurrent. The inflammation impairs and may eventually destroy the activity of the udder by spreading further in the gland after each calving. It is generally acepted that some at least of these types of mastitis are due to infection with streptococci of two or three distinct kinds. A great deal of work has been done in America, England and Germany, and a uniform technique for the recognition of the different species or varieties of streptococci involved is becoming established. The members of this group of micro-organisms are often very difficult to distinguish, and but little work on experimental infection has been found possible. Nevertheless considerable advance has been made; workers on veterinary and human diseases are finding groups of streptococci of importance in both fields of medicine and are deriving mutual assistance. Preventive hygienic measures have proved of value, but no curative treatment has so far been established.

The recent work in this country(39) has been done at the Research Institute of the Royal Veterinary College. Forms of mastitis due to other kinds of bacteria are also under investigation.

Infectious Sterility

Another animal disease, associated with streptococci of a different kind, is the infectious sterility of thorough-bred mares, which is receiving attention in the United States and in this country.

Diseases due to Infection with Sporing Anaerobic Bacilli

There is a large group of animal diseases due to infection with sporing anaerobic bacilli to which the generic name of *Closteridium* instead of *Bacillus* is now given. The great confusion in this group of organisms which formerly prevailed was very much reduced by the intensive study given to it as the cause of " gas-gangrene " in man during the war.

Black-leg or quarter-evil in cattle and sheep(40) is usually caused by *Cl. chauvoei,* but sometimes by other species. A great deal of work has been done of recent years towards devising a suitable protective vaccine,(41) and a fair amount of success has been achieved, but a completely sterile satisfactory vaccine is still needed and further work is in progress. A serum (42) has also been prepared and found active.

The first described bacillus of this group, and still one of the most important, is that which Pasteur called *Vibrion septique,* now more correctly named *Cl. oedematis maligni.* It is generally accepted as the proximate cause of death in Braxy(43) or Bradsot of sheep in Northern Great Britain, Ireland and Iceland. In this disease there is intense local infection of the abomasum and death is due to the toxin produced by the bacillus. Vaccine is used extensively to protect the sheep, and attempts are being made to improve the method of preparation. The same bacillus is also believed to be responsible for "grass-ill" in(44) young lambs in Northern England.

There are other species or sub-groups of Closteridium which are productive of fatal disease in sheep. The most important of these is *Cl. welchii* (or *perfringens*) of which at least four variants are described and distinguished by differences in the toxin which they produce, the corresponding antitoxin and the forms of disease with which they are associated. These varied types of the bacillus have been especially examined at Cambridge and at the Wellcome Physiological Research Laboratories.(45)

Cl. welchii is also one of the chief primary infecting agents in gas gangrene and some other infections in man. The subspecies or type *Cl. welchii agni* is the cause of Lamb-dysentery(46) in the north of England and Scotland, which in some years is responsible for a very high mortality in the first days of life. It is now known, as the result of work since 1928, that this can be averted for the most part by giving antitoxin directly to the lambs immediately after birth or more conveniently by vaccinating the ewes, which then communicate immunity to the lambs by way of antitoxin in the first milk.

Cl. paludis, a very nearly related bacillus, was described in 1930 in the disease known as "struck" (47) on the Romney marshes. It appears to produce its lethal toxin in the intestine.

"Pulpy kidney", described in 1907, is believed to be due to another closely allied form, *Cl. ovitoxicum.* It has been chiefly observed in New Zealand and Australia, but also occurs in Great Britain.

The *Cl. welchii* group of micro-organisms produce symptoms and death in these diseases chiefly by their toxins before there is much invasion of the tissues.

" Black disease " of sheep in Australia and the disease known in Germany as " bradsot " are probably both caused by *Cl. novyi;* the chief seat of multiplication of the bacilli is in the liver, where they cause necrosis and produce toxin.

These diseases, due to sporing anaerobic bacilli, can to some extent be prevented by the use of vaccines consisting of toxin made harmless with formalin and of the bacilli or their spores killed by heat or in some other way. These vaccines are undergoing further examination and trial.

Foot and Mouth Disease

Foot and Mouth disease has been under investigation during the last nine years by the Foot and Mouth Disease Research Committee appointed by the Ministry of Agriculture and Fisheries in 1924. The Committee has issued four Progress Reports,(48) and a fifth is at present being prepared. Papers have also been published by workers at Liverpool University.(48) Peculiar difficulties connected with observations in the field on this disease are due to its extreme infectiousness and the short time allowed between diagnosis and slaughter of the affected animals. These difficulties have been overcome to some extent by the provision at Pirbright of means for the isolation of a limited number of large animals which have been artificially infected, and the use of small laboratory animals for those aspects of the subject for which they are suitable. The infective agent is a filterable virus, the particles of which are very numerous and smaller than those of any other known virus found in animal disease. The size of the particles of virus has been estimated by the use of filters made of collodion membranes, specially prepared at the National Institute for Medical Research at Hampstead.(49) Though the virus can easily be destroyed by heat or carefully applied antiseptics or alkalies, it is very resistant to drying, and remains active for a long time in the body of an animal killed at the height of the disease, especially in the bones and when the carcase is kept chilled or frozen. It also withstands several of the methods used for the preservation of pork, or bacon by salting, etc.

Though cattle, sheep and pigs are the animals commonly attacked, small animals such as rats, dogs, cats, field voles, mice and hedgehogs can be infected experimentally, and hedgehogs and rats may acquire the disease by contact with infected members of the same species. The disease has very rarely been detected in wild animals, and whether the infection of wild animals or birds is ever of importance from the practical point of view in dissemination of the disease is unknown. One characteristic possessed in common with several other virus diseases of animals has been especially observed in foot-and-mouth disease; a particular strain of virus often becomes adapted to one species of animal, so that it much more readily infects that species than any other. Besides this kind of variability there are at least three distinct types of virus named O, A, and C, which produce attacks of disease alike clinically, but so far different that an attack due to any one of them does not give protection against the others. An attack as a rule protects for one or two years against a second due to the same type of virus. Experimentally in small animals considerable protection can be obtained against the disease with a dead vaccine, but this is difficult to prepare in sufficient quantity for practical purposes, and it has never been thoroughly tested on farm animals in the field. An antiserum can also be obtained from inoculated cattle. In large doses this antiserum gives a limited degree of protection for ten days or so, and has proved of practical value on the Continent. If a stronger serum could be obtained than is at present available, it might be useful in this country under special circumstances, though a weak serum may have undesirable effects by merely masking a mild, but nevertheless infectious, attack. Production of immunity by a combined inoculation with serum and virus has been used extensively in Germany as a means of limiting an outbreak, but the inoculated animals may act as fresh foci of infection unless strictly isolated. The policy of slaughter has kept this country a great deal freer from disease than most European countries. The source of infection in initial outbreaks often cannot be ascertained, but the possible importation of infected carcases is a serious menace.

Louping-Ill

The fatal disease of sheep called Louping-ill is very prevalent in certain parts of Scotland. The most prominent symptoms are spasms and paralyses due to involvement of the central nervous system. As was long suspected, the disease has now been shown to be transmitted by the tick, *Ixodes ricinus*. Work in the last few years at the Moredun Institute has disentangled the natural history of this disease and of another closely associated tick-borne fever, which had previously been unrecognised as a specific disease. A protective vaccine against louping-ill has been prepared, which promises well, but is still on its trial. It has been shown that sheep on infected pastures may pass through an attack of louping-ill without nervous symptoms and recover with resulting immunity. This indicates the reason why flocks are more severely affected soon after they have been placed on such pastures. It has been found at the Wellcome Bureau of Scientific Research that field voles are susceptible to infection. The virus consists of particles which are believed to be smaller than those of any other virus except that of foot-and-mouth disease. The experimental work which has thrown so much light on louping-ill has been made possible by the discovery that tame mice can be regularly infected by inoculation. Monkeys are also susceptible.

Swine Fever

An infection due to a specific virus and known as Swine fever is commonly accompanied by a secondary bacillary invader, *Salmonella suipestifer* or sometimes *Pasteurella suisepticas*. The outbreaks are of very variable severity. In the United States, Germany, Austria, and to some extent in this country, attempts have been made to control the disease by using injections of the blood serum of pigs which have recovered and been reinoculated. If the serum is given to the whole herd at the beginning of an outbreak, all the pigs may become infected by contact whilst still under the influence of the serum, and so pass through a mild form of infection. The results following this use of serum have, however, been irregular, and after trial in England this method was discontinued.

The most effective method of prevention used hitherto is a combined simultaneous inoculation with virus and serum. If the serum is of good strength and the virus of suitable activity, the result is very satisfactory. This method should only be used in an infected neighbourhood where the disease is already established, since infective cases of the disease are produced by the inoculation. Unless care is taken, infection may be introduced of greater severity than is present in the first instance. The use of the living virus in any preventive procedure is dangerous unless the strain of virus to be used has been carefully tested, and is not applicable to present conditions in this country, since it would introduce fresh centres of infection with the necessity of compulsory isolation.

Swine Erysipelas

Swine erysipelas is an important disease on the Continent and in some parts of this country, and may be very severe.

It is due to infection with *Bacillus erysipelatis suis* (*Erysipelatothrix rhusiopathiae*) and the use of serum or a combination of serum and vaccine are recognised methods of treatment and prophylaxis, especially in Germany, but both of these remedial materials need further improvement and standardisation.

The diseases of young pigs, which often cause heavy losses, are not clearly differentiated and are in great need of detailed study.

Contagious Dermatitis

Contagious dermatitis of sheep has been investigated at Cambridge(51) and found to be due to a virus, the British strains of which are identical with those examined from other countries. A very successful protective vaccine has also been prepared.

Scrapie

A remarkable disease of sheep in Scotland, known as Scrapie, has so far defied all attempts to discover its cause or to suggest useful measures for its prevention or cure. It is characterised by great restlessness and irritability, the animal continually rubbing itself against posts, etc. The disease develops slowly, but leads to wasting, paralysis and death. Certain observations on Scrapie are at present being made at the Moredun Institute.

Grass Sickness

The cause of Grass sickness of horses, a disease which may cause very sudden death, is at present quite unknown. Efforts are however now being made at the Moredun Institute to follow various lines of enquiry. The possible connection of the disease with poisonous plants or insects has been investigated in considerable detail, but with negative results, and recent investigations are being directed towards the search for a causative bacterial toxin.

Distemper

Distemper of dogs—a disease of great importance in veterinary medicine—has during recent years been investigated at the Mill Hill laboratories of the Medical Research Council, and the conclusion of Carré that the infective agent was a filterable virus has been established on a firm basis.(52) A highly successful method of protective inoculation has been worked out, and is being extensively used in this country and abroad. The difficulties of rearing and maintaining in isolation sufficient experimental puppies were overcome by using ferrets as experimental animals. This work illustrates the prime importance of finding the most suitable animal with which to carry on research into any disease. This need is even more obvious when diseases of the larger mammals are under investigation. Distemper of cats was shown to be due to a virus different from that of the canine disease.

Other Diseases

The Salmonella group of bacteria, which contains the bacilli of typhoid and paratyphoid fevers in man, provides the infectious agents which cause several serious diseases in farm animals and birds. *B. abortus equi* and *B. abortus ovis* cause abortion in mares and ewes respectively. These infections can be diagnosed by agglutination tests of the blood, though the method is difficult and much less certain in the case of the latter disease. *B. aertrycke,* which is one of the commonest causes of " food poisoning " in man, usually reaches human food from rodents, but this bacillus sometimes infects cattle, pigs, and ducks and their eggs.

B. enteritidis of Gaertner or a closely related bacterium causes diarrhoea in calves and sometimes infects adult cattle. B. *enteritidis* may also be found in milk and in ducks' eggs, and may cause a serious infection in man.

A form of " Transit fever ", an infectious disease of cattle which appears after sea transport, has been investigated at the Royal (Dick) College, Edinburgh. The pathology of Osteoarthritis of horses(53) and the question of its association with string-halt and shivering have also received detailed study at the Edinburgh College.

Diseases of Poultry

The diseases of fowls have gained in importance of late and are receiving increasing attention.

B. pullorum, one of the Salmonella group, causes " bacillary white diarrhoea " with a very high incidence and a mortality of 60 to 80 per cent. in some pens in the first week of life. Those chickens which recover retain the bacillus as a chronic infection of the ovary and their eggs in adult life are liable to be infected, with resulting infection of the chicks on hatching. The diagnosis of the disease in the adult and the elimination of infected birds is the recognised method of dealing with the disease, in addition to cleanliness and disinfection of the houses and coops. In the adult bird *B. gallinarum,* which is perhaps identical with *B. pullorum,* infects the intestine and is spread by the excreta. *Pasteurella aviseptica* sometimes causes very fatal outbreaks of fowl cholera in poultry and ducks; an antiserum can be prepared and used to cut short an outbreak. This serum may be used both as a prophylactic and for treatment. The vaccine which Pasteur discovered and used as a prophylactic is not so efficacious as the serum and has been abandoned.

Tuberculosis in fowls is usually an intestinal infection. It may become a very serious disease, especially in crowded premises. It is due to the avian type of tubercle bacillus which also occasionally infects pigs and cattle. Diagnosis can be made by means of a local tuberculin reaction on the wattle.

There are two chief diseases due to viruses which may cause serious epidemics in poultry farms. Fowl plague (54) has seldom been present in this country; but it has been shown that a protective vaccine and a serum can be made. A distinct virus, causing a somewhat similar infection, known as Newcastle disease, (55) was investigated at New Haw in 1927.

Fowl-pox is a very wide-spread disease, due to the same virus as fowl-diphtheria which is commonly associated with it. The crusts which form on the comb and the membrane in the mouth spread to neighbouring parts. Other birds in contact become infected and a high mortality may result. This disease has no relation to human diphtheria. The virus consists of very small particles, the so-called elementary bodies, which can be isolated by high speed centrifugation or filtration through collodion membranes. The size of the particles is very like that of the elementary bodies of vaccinia, about 0·1 to 0·2 microns in diameter (one micron = one thousandth of a millimetre). A very satisfactory preventive vaccine (56) has been prepared, following work at New Haw and Cambridge, from crusts obtained from the similar disease of the pigeon. The vaccine is applied to plucked spots on the skin of the body. Though the vaccine is alive, it only produces a quite local harmless infection in fowls. Its protective action recalls the analogous protection given to man against smallpox by vaccinia.

Paralytic symptoms in fowls may be due to several different causes. One prevalent form is especially known as "Fowl paralysis." (57) It is usually associated with growths of lymphatic tissue in the nerve trunks. The causes and prevention are not understood. Serious losses may result from this disease, and the subject is now being attacked at more than one research centre.

Coccidiosis, a very widespread and serious disease of poultry, is due to a protozoal parasite. Further research is needed to elucidate the relation of the form infecting fowls to those which attack other species, and also to determine the best methods of dealing with affected pens. The disease is believed sometimes to produce paralytic symptoms. Research on this infection is planned at New Haw and also at other centres.

Deficiency Diseases

The frequently fatal disease of cows known as "milk fever," (58) has been investigated especially at the Moredun Institute, its cause assigned to calcium deficiency in the blood and the appropriate treatment indicated. The somewhat similar train of symptoms comprising tetany in cattle is also attributed to mineral deficiency and is being studied at several centres.

The state of ill-nutrition in sheep and young cattle called "pine" (59) on the island of Tiree has been the subject of a joint examination by Agricultural Institutes in Scotland and has been referred to mineral deficiencies.

THE FUTURE OF RESEARCH IN ANIMAL DISEASES

The Memoranda of the Departments

In August, 1931, the Ministry of Agriculture and Fisheries communicated to the Agricultural Research Council a memorandum on the history and present position of research in animal diseases, and on developments which the Ministry considered desirable in the near future. In March, 1932, a similar memorandum was received from the Scottish Department of Agriculture.

The financial crisis made it impossible to contemplate immediate action on the scale proposed in these memoranda, but the Agricultural Research Council has taken both memoranda into careful consideration and made certain recommendations.

The Ministry of Agriculture and Fisheries pointed out that, while little research on animal diseases had been done in this country till recent years, since 1923 considerable progress had been made, though at all stations work has been restricted by want of funds. The facilities at all centres are small, and the position compares very unfavourably with that in the United States, in some Dominions and in Continental countries.

In considering desirable developments, the Ministry dealt first with the problem of obtaining a flow of well-trained recruits for the staffs of Research Institutes, hitherto lacking. A trained veterinarian has an immediate market value in the professional field, so that the amount of both research scholarships and research salaries must be fixed in relation to professional prospects.

In England veterinary education is carried on at the Royal Veterinary College, London, and at Liverpool University; in Scotland at the Royal (Dick) Veterinary College in Edinburgh and at the Glasgow Veterinary College. The condition of the Royal Veterinary College has long been unsatisfactory and was made the subject of a special inquiry by a Departmental Committee. A scheme for rebuilding and expansion of staff is now in progress. When it is carried out, the teaching staff should obtain leisure for research, and the Research Institute, built in 1923-24, will be merged in the Department of Pathology. This closer connection between teaching and research should introduce advanced students to the ideas of research. At Liverpool the Veterinary School has recently been re-organised and provided with improved accommodation. To give the best students further training, more research scholarships were, in the Ministry's view, needed. The Ministry considered that four or five were desirable, instead of the two which had been offered annually. It appeared likely that the financial crisis would lead not only to the prevention of this expansion, but to the suppression of the existing two scholarships.

As regards research itself, the Ministry favoured the concentration of development mainly in a few centres. The Ministry itself has the duty of keeping administrative control over certain notifiable and other infectious diseases throughout Great Britain, so that the Laboratory at New Haw, Weybridge, must be maintained for this purpose, and may well be used for research also, particularly on infectious diseases. The best centre for education in research methods was thought to be Cambridge. Hence the Ministry planned chiefly to expand the two institutions of the Laboratory at Weybridge and the Institute of Animal Pathology at Cambridge, while improving facilities for research at the Royal Veterinary College and at Liverpool.

The next point dealt with in the memorandum of the Ministry of Agriculture and Fisheries was a consideration of the principle which should guide the division of research among different institutions. Broadly, research activities may, the Ministry suggested, be classed under the following categories:—

1. *Academic research demanding laboratory facilities*, such as detailed biological studies of important pathogenic organisms and groups of organisms, physiological studies preliminary to pathology and leading to the definition of standards, and more detailed studies of reactions to harmful agents (including poisons and living organisms) in individual animals.

The Physiological, Pathological and Chemical Departments of the veterinary teaching centres at London and Liverpool should undertake work of this type.

2. *Longer-Ranged study of selected problems.*—Academic work and research demanding both laboratory and field facilities. The subjects covered would be somewhat similar to those indicated in the preceding paragraph, but the kind of work would be different and be directed to more intensive and prolonged study of selected problems.

The Institute of Animal Pathology at Cambridge was designed for work of this type.

3. *Scheduled Diseases and Diseases of Immediate Importance.*—The investigation of scheduled diseases, of which the most important are Foot-and-Mouth Disease, Swine Fever and Sheep Scab, and of clinically similar diseases from which they have to be differentiated.

The investigation of diseases that may very possibly become scheduled, such as Contagious Abortion and Tuberculosis (with special reference to immunisation).

The investigation of urgent local problems demanding resources greater than those possessed by veterinary advisory officers.

The study of poultry diseases.

This group of investigations would continue to be assigned to the Ministry's Laboratory at Weybridge.

It was not proposed, however, that these lines of demarcation should be rigid. An investigator at an academic centre may, the Ministry pointed out, strike a problem of practical importance, while one who is merely aiming at practical results may well follow up a line of enquiry of theoretical interest. The Ministry then gave instances in detail of the kind of problem which should be assigned in the first instance to the various centres of research. For example, at the Royal Veterinary College, London, attention might be given to morbid anatomy and histology, to certain groups of pathogenic bacteria, and to animal parasites of importance in veterinary pathology. At Liverpool special study might be made of Johne's disease, of anaerobic infections, of pathological problems brought by the Lairage and Abattoir Authorities, and of pathological haematology. At Cambridge the programme might include research on such subjects as filterable viruses, the *B. welchii* group of organisms, cellulose digestion of the ruminant, gastro-intestinal parasites, the biochemical aspect of sheep diseases, the pathological changes associated with deficiency and excess of certain vitamins, and the possibilities of protecting calves against tuberculosis by the use of the BCG vaccine. At the Ministry's Veterinary Laboratory at Weybridge, and the station at Pirbright, in Surrey, the special investigation under the supervision of an expert Committee of foot-and-mouth disease would be continued. In addition, further work might be undertaken on swine fever and swine erysipelas, on tuberculosis, contagious abortion, helminth infections and poultry diseases.

As regards such auxiliary subjects as entomology and helminthology, the Ministry considered that the provision for the study of fundamental entomology would be adequate when account was taken of the impending developments at Cambridge in connection with the Rockefeller benefaction, and the strengthening of the staff of the Institute, which was proposed, should enable attention to be given to applied entomology. On the other hand, as regards parasitic worms, the only institute in England devoted specifically to the subject of helminthology is the Institute of Agriculural Parasitology in the London School of Hygiene and Tropical Medicine, though there is also a Lectureship in Helminthology at Edinburgh University. As the Ministry stated, little or nothing is known of the normal physiology and biochemistry of helminths, and research in these subjects might give results of scientific interest, and open up new lines of approach to the problem of anthelmintic measures. Thus, the best policy might well be to develop the study of general helminthology as an independent science, while providing the services of a helminthologist on the staffs of Animal Disease Institutes when required.

The Ministry therefore favoured the strengthening of the staff of the Institute of Agricultural Parasitology and the development of investigations by the Institute in co-operation with other Departments of the London School of Hygiene and Tropical Medicine.

The development of research in the teaching institutions will require accommodation for housing small animals; but, when the stage which needs large animals is reached, facilities should, in the Ministry's view, be given at the existing field stations at Weybridge, Cambridge or Moredun. This arrangement will need, and help to produce, close co-operation between the two types of Institution.

The memorandum then considered in detail the increase of staff which would be necessary at the various research centres to carry out the work proposed, the necessary capital expenditure and the increase in annual maintenance charges.

In the memorandum prepared by the Department of Agriculture for Scotland, an account is given of the formation of the Animal Diseases Research Association in 1920 by a Committee of representatives of the Highland and Agricultural Society, the Scottish Chamber of Agriculture and the National Farmers' Union of Scotland. An estate was later bought at Moredun, near Edinburgh, and the Association moved there from the Glasgow Veterinary College in 1926, the biochemical department being housed at the Royal (Dick) Veterinary College. Towards the cost of more recent extensions of staff a further sum from a private benefactor, amounting to £10,000, has been obtained.

Among the diseases on which researches have been carried out and have already led to practical results may be mentioned: lamb dysentery, braxy, milk fever, and louping-ill.

Research which has not yet reached such an advanced stage has also been undertaken on grass sickness in horses, scrapie in sheep, and "pine" in sheep and calves; enzootic abortion in ewes is also being investigated in collaboration with the Rowett and Macaulay Research Institutes.

To deal with bovine contagious abortion a special Committee has been set up, to which further reference is made later in this Report.

The Department's memorandum states that while the Royal (Dick) Veterinary College is primarily concerned with teaching, a certain amount of research has been done by the staff, consisting of work on milk fever, joint disease in horses, the general problem of sterility in farm animals, transit fever, and, in fowls, bacillary white diarrhoea and coccidiosis. Regarding the last named disease, statistical and other data have been collected during the past ten years.

The memorandum refers to the attempt being made at the Hannah Dairy Research Institute, with a grant from a private fund at the disposal of the Medical Research Council, to eradicate bovine tuberculosis from the dairy cattle in a prescribed area. (31)

In considering desirable developments in the study of animal diseases in Scotland, the Department for Agriculture expressed the hope that an increase in number might enable the senior members of the staff of the Royal (Dick) Veterinary College to devote a considerable amount of their time to research work, so that, apart from other reasons, advanced students might become familiar with research methods. In consultation with the College, the Department approved a scheme for increasing the staff by the addition of 3 new senior and 9 new junior posts at a cost of £7,000 for the first year, though, pending the reorganisation of the College, the Treasury had only been able to sanction an increase of £1,600 in the annual grant of £4,000, which provided for adjustment of salaries, the appointment of 2 new junior assistants and an increase in laboratory staff.

Besides the extension of the work at Moredun and the Dick College, the Department favoured an increase in the investigations on helminthology carried on by the Lecturer in that subject in the University of Edinburgh. Dr. T. W. M. Cameron, at that time Lecturer, was giving special attention to the bionomics of the lesser liver fluke of sheep, and to the bionomics and possible control of round worms in sheep. The Department referred to the favourable opportunities existing in Edinburgh for co-operation between workers on animal diseases and those concerned with allied subjects. Mention was also made of the investigations into the deficiency diseases of sheep undertaken by the Rowett Research Institute, Aberdeen, in collaboration with the Bacteriology Department of Edinburgh University. They expressed their concurrence with the views of the Ministry of Agriculture and Fisheries on the award of Veterinary Research Fellowships. Among the subjects to which, in the opinion of the Department, more attention should be given, or in which it was desirable to continue or initiate research, were bovine contagious abortion, mastitis, braxy, louping-ill, scrapie, grass-sickness in horses and enzootic abortion in ewes.

RECOMMENDATIONS OF THE AGRICULTURAL RESEARCH COUNCIL

The Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland asked the advice of the Agricultural Research Council on these their proposals for the reorganisation of research in animal diseases. The Animal Diseases and Nutrition Committees of the Council accordingly considered the schemes of the two Departments at length and in detail, and made certain recommendations.

Research Studentships

The Committees agree with the Ministry and the Department "that the first step in extending research must be to make sure of a flow of well-trained recruits." Such recruits can best be obtained first by improving the Veterinary Colleges, and then by offering studentships. Owing, however, to the financial crisis, even the provision already made for four or five research scholarships in Agricultural Science, estimated by the Ministry of Agriculture and Fisheries to be of a value of about £270 a year each (maintenance, £200; fees and travelling, £70) had to be withdrawn. The Agricultural Research Council, however, thought this point in the scheme so important that, from their own limited research fund, they agreed to award in June, 1932, two Studentships for Research in Animal Health, tenable for three years and of an inclusive value of £300 per annum. Subsequently it was decided that the cost of these Studentships should be found from savings on other Development Fund services on the Departmental Votes. In June, 1933, two more such Studentships were awarded, for which provision had been approved by H.M. Treasury, and, with the consent of H.M. Treasury, once more placed on the Estimates of the Agricultural Departments. The Council hope that the existence of these Studentships, and the openings which exist in the field of research in animal health, will rapidly become more generally known in Universities and Colleges. The work of the Students, attached as they are to Research Institutes during the period of their training in research methods in this country, constitute in themselves and at once a contribution to research programmes.

Veterinary Education and Research

The close connection between education and research led the Animal Diseases and Nutrition Committees of the Agricultural Research Council to take the whole of these allied subjects into earnest consideration. The Animal Diseases Committee co-opted Major-General Sir John Moore and Mr. R. E. Montgomery, Adviser on Animal Health to the Colonial Office, and wish to express their thanks for the help thus given, and their regret at the untimely death of Mr. Montgomery. They also wish to acknowledge the valuable assistance which they have received from Sir Ralph Jackson and Mr. P. J. L. Kelland, the former and present Chief Veterinary Officers of the Ministry; as well as from Dr. W. H. Andrews, Director of Veterinary Research to the Ministry, Professor W. W. C. Topley and Dr. P. P. Laidlaw of the staff of the Medical Research Council, who became members of the Animal Diseases Committee at a later date.

The Committees found that there was some general dissatisfaction both with parts of the training and with the professional prospects of veterinary surgeons. Nevertheless, the profession itself has done splendid work, and, through the Royal College of Veterinary Surgeons, has kept steadily before it the need for raising the qualifications of its members to the highest possible standard. The Committees were glad to learn that changes in the curriculum and an extension of the time of training from four years to five were to be made.*

At all Veterinary Colleges it is possible for students to matriculate in a University, but at Liverpool alone is the

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* The new five-year curriculum came into force in October, 1932.

Veterinary Department itself a School of the University. The Committees regard this as the ideal to be aimed at in all cases, and hold that the emoluments of the teachers and the amount of time they can spare for research should be raised with this object in view.

With improvement in the Colleges, it is natural to hope that an increasing number among the abler men will devote themselves to research. But here, as the Departments recognise, a difficulty shows itself. To carry most of these men on after their undergraduate training, scholarships or studentships are necessary. The income of these emoluments and the salaries it is possible to pay to the holders of junior posts in Research Institutes compare unfavourably with the professional earnings of a practising veterinary surgeon.

The Committees think that full consideration should be given to this difficulty, which is mainly, but not exclusively, financial. While they fully realise the extent of the ground to be covered by those training to be veterinary surgeons, they hope that it may be possible to give some further relaxation in the time needed for a professional qualification to those of high scientific achievement, and that an avenue to professional practice may be opened to those who have spent time on research. The Committees regard it as desirable that many among the juniors in a Research Institute should contemplate passing on either to teaching posts or to professional practice, and hope it may be made possible for them to do so.

Veterinary Schools and Colleges

Among the Institutions from which a supply of candidates for the studentships in Animal Health and the staffs of Research Institutes may be drawn, the Veterinary Colleges hold an important place. Moreover, as urged in the memoranda of the Departments, higher education should be linked with research, and the staffs of Veterinary Colleges should have enough leisure from teaching duties to enable them to advance knowledge in the subjects with which they are concerned. The Animal Diseases and Animal Nutrition Committees of the Agricultural Research Council go further, and hold conversely that it is well for most members of the staffs of Research Institutes to do some teaching, though they recognise that this is a rule to which exceptions should be allowed.

The Memoranda of the Departments made it necessary for the Animal Committees of the Agricultural Research Council to inspect the Veterinary Schools as part of their survey.

The Royal Veterinary College

The Royal Veterinary College in Camden Town has for a long time been in a state which, compared with the spacious and well-planned Colleges in several foreign countries, may fairly be said to constitute a national disgrace. With cramped accommodation and ruinous buildings, it was becoming more and more difficult to carry on even the regular routine of teaching, and the staff had little opportunity for research. However, in 1923-24, a Pathological Research Institute was built on ground adjoining the College at the cost of some £34,000, of which £31,500 was granted from the Development Fund. The Institute was first established in the College in 1912, but accommodation had to be found for it in the overcrowded College buildings.

By 1930 the Governors had collected some £90,000, a sum which has since been further increased, towards rebuilding the College itself, and a promise of £150,000 from the Development Fund was made to them. The financial crisis of 1931 made it imperative to postpone this payment, but part of the proposed buildings are now being built by the Governors with their own funds, and it is hoped to begin the erection of the central College block during 1934. The College received in the Academic Year 1933-34 a Maintenance Grant from the Ministry of Agriculture and Fisheries of £5,000.

The Animal Diseases Committee of the Agricultural Research Council visited the Royal Veterinary College in November, 1931, and, in conference with the staff, examined the present research work and the proposals for developing it in relation to the teaching departments under the reorganisation scheme. They found that, owing to the teaching duties of the small existing staff of the College, research was almost entirely confined to the separate staff of the Pathological Research Institute, which then had no teaching responsibilities. Under the College re-organisation scheme, while the Institute retains its title, if forms part of the Department of Pathology, and the Director of the Institute has been appointed Professor in that subject.

At the date of the visit of the Commitee of the Council, the Institute staff were engaged in an intensive study of mastitis in the different forms which this disease takes. Attention was also being paid to methods of diagnosing and controlling Johne's disease, and in a limited degree to research on contagious abortion as a check on the mastitis investigation.

The Committee were also shown the plans for the rebuilding of the College. At a later date a Sub-Committee of the Animal Diseases and Nutrition Committees, in consultation with Sir

Frederick Hobday, the Principal, and other representatives of the College, and subsequently with representatives of the Ministry of Agriculture and Fisheries, examined the scheme for the full staffing of the College, and, with a view chiefly to securing adequate facilities for research, made certain suggestions, which led to a final scheme.

The recommendations made by the Council's Committees provided for Departments of Surgery and Obstetrics; Medicine and Materia Medica; Animal Husbandry and Hygiene; Physiology and Chemistry (grouped with Physics and Pharmacology); Anatomy, Histology, Biology and Embryology; and Pathology. The Head of the Department of Pathology would also be Director of the Research Institute, and his staff would consist of four Readers (in Pathology, Biochemistry, Bacteriology and Parasitology), three Lecturers (in Pathology, Bacteriology and Parasitology) and three Demonstrators. This, because of the special research duties, would be the largest Department in the College. For the rest of the Departments a total staff of eight Readers, eight Lecturers and five Demonstrators was proposed, in addition to the Heads of Departments. It was contemplated that the Head of the Department of Animal Husbandry and Hygiene would be an expert in nutritional science, that at least one member of the staff would have a practical knowledge of animal husbandry and that one member would have a knowledge of the physiology of reproduction. It was, of course, clearly realised that the scheme could only be carried into effect as funds and suitable personnel became available. The Council, moreover, wholeheartedly support a proposal subsequently made for developing a section within the College to be devoted to the study of Preventive Medicine.

It is the Council's confident belief that the adoption of a general scheme of reorganisation along these lines would result in a notable improvement in the facilities available for the training of Veterinary students, both for a professional career and for service in research.

The incorporation of the Research Institute in the Pathological Department of the College, suggested by the Ministry of Agriculture and Fisheries and supported by the Agricultural Research Council, and the modifications introduced into the scheme of staffing, inevitably made it desirable to revise the building plans. The plans were once more examined with the help of Major H. P. G. Maule, the Governors' Architect, and Captain E. Gunn, Superintending Architect to the Ministry of Agriculture and Fisheries. Finally, the Governors invited Profesosr D. M. S. Watson, a member of the Agricultural Research

Council, to join the Board of the Royal Veterinary College. Professor Watson's intimate knowledge of laboratory management, and his recent experience of laboratory building and equipment, proved very useful, and the changes made in the plans on his advice will, it is hoped, lead to an increase in both efficiency and economy. Recently the Governors of the College have also invited the Secretary of the Agricultural Research Council to be present at meetings of their Building Sub-Committee.

Royal (Dick) Veterinary College, Edinburgh

In November, 1931, the Animal Diseases Committee of the Agricultural Research Council visited Edinburgh and inspected the Royal (Dick) Veterinary College and the Animal Diseases Research Association Institute at Moredun. Again, in April, 1933, a Sub-Committee, on which members of the Council were assisted by Professor H. S. Raper, examined the work of these Institutions in greater detail.

The Royal (Dick) College plays an important part in veterinary education, the number of students ranging about 190 at any one time. The buildings, though not elaborate, are modern and well arranged, having been erected mainly in 1914-16 at a cost of about £74,000. Of this total, £24,040 were found from the Education (Scotland) Fund, £7,682 from the Agriculture (Scotland) Fund, and £16,560 from moneys placed at the disposal of the Department of Agriculture for Scotland under the terms of the Corn Production Acts (Repeal) Act, 1921. The Department of Agriculture made subsequent capital grants amounting to about £6,000 over a period of five years.

The income for 1930-31 of a total of about £12,200 was derived from grants from the Department of Agriculture for Scotland (£3,656); Education Authorities (£129) and County and Town Councils (£292); from Students' fees (£3,844) and Veterinary practice fees (£2,562); from endowments and property (about £1,000); from a special grant for equipment from the Carnegie Trust (£426); and from miscellaneous sources (£337). For 1931-32 the grant offered by the Department of Agriculture for Scotland was increased to £5,600. In addition a few small Development Fund grants for special investigations have been made during the past few years.

The salaries paid seem unduly low, and the time of the staff is so fully occupied with teaching that they have little opportunity for research. Nevertheless, the Principal, Professor O. Charnock Bradley, and Professors R. G. Linton and W. M. Mitchell, have done a creditable amount of work on the subjects specified in the memorandum of the Department of Agriculture for Scotland. Proposals for strengthening the College staff have been considered by a Sub-Committee of the Animal Diseases and Nutrition Committees of the Council in consultation with Principal Bradley. These proposals have now been re-submitted in a revised form.

The Animal Diseases Research Association

The Animal Diseases Research Association's Institute at Moredun was founded by the independent initiative of Scottish agriculturalists, and receives private contributions towards the cost of maintenance. In the financial year 1932–33 the income of the Association amounted to about £9,214, consisting of £337 from subscriptions; £1,507 from donations of County Councils, Agricultural Societies and individuals; £818 from interest on endowments, including interest on a Staff Endowment Fund, valued at cost at approximately £12,276, which was formed by a private benefactor; £2,025 from sale of Laboratory products, from tests, and from miscellaneous receipts; and £4,446 by way of Development Fund grant through the Department of Agriculture for Scotland. The connection with local farming gives the Association an independent status which is much valued, and should be maintained in any scheme for closer connection with the University of Edinburgh and the Royal (Dick) Veterinary College.

At the time when the Association was formed, a grant of £3,500 was made for the purpose of capital expenditure and for endowment from the funds made available to the Board of Agriculture for Scotland by the Corn Production Acts (Repeal) Act, 1921. The work was started in the Veterinary Colleges at Edinburgh and Glasgow. Later the whole of the work was transferred to Edinburgh, and a Field Station was built at Moredun with the assistance of a grant of £18,000 from the Board (now the Department) of Agriculture.

The Association has been chiefly engaged on research on diseases of importance in Scotland. Among the investigations specially prominent at the time of the visits may be mentioned the following:—

The work on lamb dysentery has been brought to a successful conclusion and the manufacture of an effective serum handed over to a commercial firm, Messrs. Burroughs and Wellcome. Louping-ill, a virus disease in sheep, has been shown to be carried by ticks and associated with another disease hitherto unsuspected, tick-borne fever, and the conditions necessary for the transmission of the disease by the tick have been demonstrated. A survey of the distribution of the tick concerned in Scotland (*Ixodes ricinus*) is being made. A dead vaccine has been made which has preventive effects and is now being tested experimentally in the field. The difficult problem of the cause of scrapie, a chronic disease of sheep, is being tackled. The cause of the disease and the method of transmission are unknown. Grass Sickness in horses is being investigated from the physiological and bacteriological aspects, since a study of plants and insects in affected districts has thrown no light on its cause. "Pine" (59) has been investigated in the Island of Tiree jointly by the Animal Diseases Research Association and the Rowett and Macaulay Institutes. It has been shown to be a deficiency disease which can be cured or prevented by adding crude ferric oxide to the diet, though further investigation is required to explain the exact manner in which the chemical composition of the soil affects the herbage and the grazing animals, and to improve the method of treatment. The mortality from braxy in sheep appears to have been reduced in some thousands of sheep from 6.73 to 0.64 per cent. by inoculation with a dead vaccine.

Generally, the Council's Committees have formed a very favourable impression of the work of the small staff of the Moredun Institute, and particularly of the difficult team work on the obscure disease of louping-ill and the associated tick-borne fever. The biochemical investigations are of special interest, as little study has been made in this country of the biochemistry of domesticated animals; the researches in progress appear to have been well chosen and are being carried on with enthusiasm.

The Committees of the Agricultural Research Council felt that, with local differences, the problem in Edinburgh resembled that in London—again, it was desirable to link together, in as close co-operation as possible, education and research and the institutions charged primarily with each, and to bring them into definite relations with the University. The history of the Animal Diseases Research Association threw inevitable difficulties in the way of any form of amalgamation, but a conference was arranged between a Sub-Committee of the Agricultural Research Council and representatives of the Royal (Dick) College and the Animal Diseases Research Association. After this Conference, with the good will of all concerned, which the Agricultural Research Council cordially acknowledges, a start has been made in the study of possibilities. The question has been referred by the Governing Bodies of both institutions to the Research Committee of the Animal Diseases Research Association, whose report the Agricultural Research Council has received, since the end of the period covered by this Report of the Council.

Liverpool Veterinary School

The Veterinary School at Liverpool has the distinction, unique in Great Britain, of being an integral part of the University. A Sub-Committee of the Agricultural Research Council, visited Liverpool on the 11th and 12th January, 1932, and conferred first with the Vice-Chancellor of the University and then with Professors S. H. Gaiger (Pathology) and J. T. Share-Jones (Anatomy).

There are now fifty or sixty veterinary students. They attend classes in their preliminary subjects with the medical and dental students. The Pathological Department earns a considerable sum by routine testing work for tuberculosis, etc., and by the making and sale of vaccines in small quantities. This is felt by the staff to be useful, as it brings in material for teaching and research, and keeps the School in touch with the veterinary profession and with farmers. Teaching is well organised, and is very successful in passing students through the veterinary examinations.

All the qualified staff of the Department are engaged in research as well as teaching, and are sometimes helped by distinguished pathologists visiting Liverpool from overseas. Among the subjects of research may be named pregnancy disease in ewes, Johne's disease, including the efficacy of johnin and other tests, nephritis in dogs, keel disease of ducklings, and the bacterial contents of market milk with special reference to bovine abortion. The Veterinary Advisory Officer also acts as field officer to the Department of Pathology in the investigation of diseases. New premises were acquired for the School in 1928, and these are being improved and equipped, and animal accommodation is being built, with the aid of a £ for £ grant of £15,000 from the Development Fund. The School receives an annual block grant from the Ministry of Agriculture and Fisheries of £2,700.

The Sub-Committee thought that the state of the Pathological Department was very satisfactory, and, as long as the numbers of students in this School remain approximately as at present, have no criticism or suggestions to offer.

Glasgow Veterinary College

The Scottish Department of Agriculture decided that it could only subsidise one Veterinary College, and chose the Royal (Dick) College at Edinburgh. Nevertheless, the authorities at Glasgow determined to maintain the Glasgow Veterinary College from other resources. The total income is very small, about £5,000 a year in all.

A Sub-Committee of the Agricultural Research Council, visited this institution on the 11th January, 1932. They report "The outstanding feature about the College . . . was the vitality and quality of the human material as compared with the literally dilapidated condition of the College buildings." Results of the Royal College of Veterinary Surgeons' examinations show that the quality of teaching is unmistakably high, the Fitzwygram prize having been won by Glasgow students three times in five years. During the last three years the number of students has risen from 52 to 135.

The Principal, Professor Whitehouse, and his staff, only two of whom are whole-time, are so fully occupied with teaching that they have little opportunity for research.

Future Policy for Research in Animal Disease

After considering various possibilities for strengthening the organisation for research, the Ministry of Agriculture and Fisheries in their memorandum favoured an increase in staff at the Royal Veterinary College and at Liverpool, to improve the teaching, to give the staff leisure for research, and to provide for the preliminary training of advanced students in research methods. The Ministry also planned considerable developments at their Veterinary Laboratory at Weybridge and at the Institute for Animal Pathology at Cambridge. A close examination of the two institutions at Weybridge and Cambridge by the Agricultural Research Council therefore became desirable.

The Ministry's Laboratory at New Haw, near Weybridge

On 16th February, 1932, the Animal Diseases and Nutrition Committees visited New Haw, and consulted with Dr. Andrews, the Director. The staff at that date, three full time research workers, in addition to the Director, seemed to them inadequate for the duties assigned to the Laboratory in connection both with the scheduled diseases of animals, and with those diseases of pigs, poultry and other farm stock, which can most appropriately be studied at New Haw. This inadequacy remained, even though members of the inspectional staff are seconded to the Laboratory to carry on routine diagnoses and the making of sera and vaccines, the demand for which was growing very rapidly. While it was appreciated that some of the Inspectors seconded for routine work of this nature gave useful help also in research, it was inevitable under the existing arrangements that members of the research staff should be occupied to some extent with the supervision of diagnoses and of vaccine and serum manufacture. Besides routine work, investigations were proceeding on swine fever and the survival of its virus, on helminthology, and on poultry diseases, while an extension of reseach on contagious abortion was being planned.

The Committees reserved for future consideration the difficult question whether the manufacture of vaccines and sera should be undertaken as a normal part of the work of State-aided laboratories. As regards routine diagnoses, they agreed with Dr. Andrews that it was of great advantage to a research staff to have access to a large mass of pathological material collected from all over the country, though, when this work is heavy, a separate staff becomes desirable. They regarded as an immediate need the addition of a chemist to the research staff, and were fortunate enough to secure funds from the Empire Marketing Board which allowed the appointment of Dr. H. H. Green (who had gained much experience of animal diseases at the Veterinary Laboratories at Onderstepoort, South Africa) for one year, when an opportunity for a more permanent arrangement occurred.

It was agreed that pig and poultry diseases formed the most urgent subject of enquiry, and that at the earliest opportunity additional provision for their investigation should be made. The Committees also suggested that one or more of the holders of the Studentships in Animal Health could usefully obtain part of their training at Weybridge, and that possibly, by arrangement with the authorities of the Universities or Colleges to which they are attached, some of the Veterinary Advisory Officers should move their headquarters to the Ministry's Veterinary Laboratory for a time. These recommendations were obviously only intended to be temporary expedients, to be adopted until financial conditions permitted of the strengthening of the permanent staff of the Laboratory, a subject which the Council are glad to learn has been taken into full consideration after the close of the period covered by this Report.

In order that a permanent scheme might be in readiness when funds became available, the Council's Committees subsequently examined, in consultation with representatives of the Ministry, the proposals relating to the Laboratory at New Haw contained in the Ministry's memorandum on the Re-organisation of Animal Diseases Research. They urged strongly that, having regard to the fact that the execution of the greater part of any programme of research on pig and poultry diseases, as well as on other problems, urgent from the administrative point of view, must fall to the Ministry's Veterinary Laboratory, the needs of that Laboratory should be met as soon as possible, and before additions were made elsewhere. The scheme of permanent staffing as recommended by the Council, provided for a Director; a senior biochemist, with a biochemical research officer; a senior clinical pathologist with a pathological anatomist as his assistant; a senior bacteriologist with two research officers; a senior officer and a research officer for poultry and rabbit diseases; and a junior officer for field inquiries.

It was further recommended that there should be a separate building and staff for routine diagnosis and vaccine preparation at Weybridge.

Cambridge Institute of Animal Pathology

The proposals formulated by the Ministry of Agriculture and Fisheries for the increase of work on animal diseases contemplated also, as has been said, development at the Institute of Animal Pathology at Cambridge. The Animal Diseases and Nutrition Committees of the Agricultural Research Council therefore paid a preliminary visit to this Institute as early as November, 1931. They later conferred with Professor J. B. Buxton in London and appointed a special Sub-Committee, which again visited Cambridge on 22nd February, 1933.

The work going on at the Institute was found to be both interesting and important. Among many other researches mention may be made of those which have been carried on for several years by Professor Buxton in collaboration with Dr. Stanley Griffith of the staff of the Medical Research Council and Dr. R. E. Glover of the Institute of Animal Pathology on the efficacy of the BCG (Bacillus Calmette-Guerin) vaccine as a protection from tuberculosis. Calves were given two intravenous doses of BCG and later one large test dose of virulent *B. tuberculosis*. They were then slaughtered at intervals and compared with unvaccinated animals similarly tested. The amount of immunity observed up to the date of the Sub-Committee's visit, though encouraging, indicated the need of further experiments, and a careful control and standardisation of the BCG vaccine. The work is being continued on the advice of the Joint Committee on Tuberculosis of the Medical Research Council and the Agricultural Research Council, with financial support from the funds of the Medical Research Council and the Development Fund.

Dr. Glover has been making and testing different preparations of tuberculin in the hope of eliminating the doubtful reactions which are reported not uncommonly. A " synthetic " tuberculin has been made, which it is believed will not cause non-specific reactions.

Mr. T. J. Bosworth was working at the improvement of the diagnosis of a bacterial infection of sheep said to cause abortion in flocks in the Eastern area on a considerable scale, and of an infection of mares causing sterility, believed to be streptococcal in origin.

Attention may also be drawn, in view of the urgency of research on pig diseases, which the Council have stressed, to the experiments of Professor Buxton and Mr. H. R. Allen on the standardisation and improvement of antiserum for the treatment of swine erysipelas.

The strains of *B. welchii* from sheep were being studied by Mr. A. J. Wilsdon under Professor Buxton's direction. The work on sheep appeared to the Sub-Committee to be of much importance for the elucidation of the varieties of anaerobic bacteria which infect sheep and their corresponding antitoxins. Dr. J. Stewart was making an interesting study on the influence of parasitic infestation on the course of digestion in sheep, and had shown that the rate of protein utilisation fluctuated with the degree of infestation, though the utilisation of fat and carbohydrate did not appear to be influenced. The Sub-Committee expressed the hope that this work would be extended.

Mr. J. S. Steward has worked out the life history of a nematode worm, the adult form of which is found associated with the lesions of fistulous withers in horses, and by so doing has made a notable contribution to the study of helminth life histories. Dr. C. Lapage was endeavouring to invent a technique for keeping intestinal nematodes alive on laboratory media through their life cycles, and has succeeded with larvae up to and beyond the infective stage. Culture of the adult is a much more difficult problem, but if a satisfactory technique is found, all studies of curative treatment as applied to adults should be facilitated, and an explanation might be forthcoming of the observation that flocks grazed under similar conditions over fields which have been equally exposed to infection often differ markedly in the infection they acquire.

While being favourably impressed with the work going on, the Agricultural Research Council wished that no opportunity should be missed of useful co-operation with other allied University Departments, especially that of Human Pathology. It was the hope of such co-operation that led to the choice of Cambridge as the home of the Institute of Animal Pathology. The steps taken by the Council to get adequate consideration for the relation of the Research Institutes to the University and its Departments are described above (p. 97).

Scotland

As regards the scheme for the development of research in animal diseases put forward by the Scottish Department of Agriculture, the Committees of the Agricultural Research Council have little more to say at this stage. They concur with the Department in desiring that the staff of the Royal (Dick) Veterinary College should have time for research. They think that reciprocally more members of the staff at Moredun might contribute towards the teaching strength of Edinburgh. They agreed that money would be well spent in increasing the facilities for work at Moredun, and have great hopes that the enquiry carried out by the Research Committee of the Animal Diseases Research Association, with the cordial approval of the Governors of the Royal (Dick) College, may lead to close co-operation of the Association with the College, and eventually with the University of Edinburgh.

PARASITOLOGY

Helminths and other parasites

Many of the diseases of animals are due to metazoon parasites. In particular, diseases carried by ticks, and those due to helminths—parasitic worms—are the cause of enormous losses to farmers.

The very serious losses which result from those diseases of all domesticated animals caused by parasitic worms render it necessary to discover practicable methods of avoiding infection, or, if that be impossible, of killing the parasites before they have done much damage.

The first step in such researches is to determine the parasite involved; this is purely a matter of systematic zoology, a branch of knowledge now far advanced. It is then necessary by a general survey to determine how far the similar diseases of different districts of Britain are caused by the same helminths. Such studies have made a good beginning.

The next stage, sometimes a most difficult one, is to make out the life history of the parasite. This may be a very complex story; the liver fluke of sheep, for example, spends one stage of its development within the body of a small fresh-water snail.

When the life history is known, it is next necessary to discover the conditions which determine infection, the length of time in which the parasite can remain alive in the soil, and the possibility of insuring its death before it can enter a new farm animal.

The life history of the most important parasitic worms of farm animals is now known at least in outline, but the details, which are of practical importance, require much further investigation.

The possibility of killing the parasite either before its entrance into its host, or by an helminthicide afterwards, is far more difficult to determine. Analogy with comparable cases suggests that only fundamental studies, without any obvious practical significance, of the physiology of many worms at all stages of their life histories will enable effective treatments to be invented. Such studies are technically difficult, and have scarcely even been begun anywhere in the world. Finally the possibilities of an immunity following on infection must be investigated.

Work on parasitology is now going on in many places. The chief centre for fundamental investigations bearing on agricultural problems, whether affecting animals or plants, is the Institute of Agricultural Parasitology at the London School of Hygiene and Tropical Medicine, and its Field Station near St. Albans, which is maintained by Development Fund grants. A still wider field is covered by the Molteno Institute of Parasitology at Cambridge. In the Department of Zoology at Edinburgh a Lecturer in Helminthology, who teaches veterinary as well as scientific and medical students and undertakes a wide programme of research, is maintained from University resources and from the Development Fund jointly. Investigations directed to the solution of definite problems of animal health are in progress at the Institute of Animal Pathology, Cambridge, in the Veterinary Laboratory of the Ministry of Agriculture and Fisheries near Weybridge, and in the Moredun Institute of the Animal Diseases Research Association at Gilmerton, Midlothian.

The Molteno Institute of Parasitology at Cambridge was founded in 1921 through the generosity of Mr. and Mrs. Molteno. The Animal Diseases and Nutrition Committees of the Agricultural Research Council visited the Institute in February, 1932. Work is carried on upon broad lines, chiefly on animal parasites. The Institute has given much attention to ticks, and now has the largest collection in the world.

The work of the Institute was explained to the Council's Committees by Professor G. H. F. Nuttall, formerly Director, in the unavoidable absence of the present Director, Professor D. Keilin. Ticks, which are carriers of piroplasmosis in cattle, and of corresponding diseases in the horse, sheep and dog, have been specially studied. Work has also been done, especially during the war, on blood-sucking insects such as mosquitos and lice. With the aid of a grant from the Medical Research Council, Dr. P. Tait and Miss M. Vincent had been working on malaria, studying the life history of the parasite by the use of canaries. It is hoped that a curative agent may be found in a synthetic compound. The late Mr. M. D. Macgregor, in collaboration with Dr. E. Hindle, had worked on a method of artificial feeding of ticks, and Miss M. Bishop on the cultivation of parasitic protozoa *in vitro*. Dr. H. P. Bayon had identified four diseases of the domestic fowl, which appeared to be influenced by lack of vitamins A and B1. He could cure some cases of paralysis by feeding with greens and bakers' yeast.

The Committees for Animal Diseases and Animal Nutrition of the Agricultural Research Council visited the London Institute of Agricultural Parasitology on 11th May, 1932, and heard an account of the work in progress from the Director, Professor R. T. Leiper. More recently a Sub-Committee has examined the work at St. Albans, but its report is still under consideration. An early task of the Institute had been to work out the morphology and life history of certain worms, in the course of which the Institute had trained three or four Veterinary helminthologists. They were at the time of the visit of the Council's Committees investigating the effect of the new methods of frequent cutting of pasture grass on infection by helminths, the eggs of which take a week to a fortnight to develop. It seems that adjusting the intervals between stocking an enclosure may be the best way of preventing infection. Goats, reared by hand and kept free from parasites, are largely used for experimental purposes at the Field Station, as being subject to infection by the same helminth parasites as sheep, but more easily handled and fed under the conditions existing at the farm.

The staff of the Station are investigating the period of survival of infective larvae on grass; whether adult goats, as is believed to be true of sheep, acquire an immunity to helminth attack under natural conditions; and the influence of rotational grazing on the amount of helminth infection. Experiments to test the effects of malnutrition on the susceptibility of pigs to Ascaris infection are also in progress. The whole of these investigations are rendered exceptionally difficult by the known fact that animals vary greatly in their individual susceptibility to parasitic infection. There is need for more work on the normal physiology of helminths.

It is very desirable to spread some of the knowledge already gained among farmers: e.g., liver fluke in sheep could be greatly lessened by killing the molluscs in small reservoirs of water during a dry summer, but no one would spend the necessary money on control. The same difficulty in getting existing knowledge used appeared in connection with hook worm infection in man, on the investigation of which the Rockefeller Foundation had spent very large sums. Field work by Veterinarians co-operating with the Institute was also desirable, especially on such problems as the effect of drugs.

Helminthicides, with special reference to the control of the nematodes which are the common cause of verminous gastritis in sheep in England, are also being studied by Colonel W. A. Wood at the Institute of Animal Pathology, Cambridge. The mixture of copper sulphate and sodium arsenite, which has proved so efficacious against *Haemonchus* in South Africa, is by itself of little use in this country. Colonel Wood is experimenting by adding other ingredients. Reference has already been made to the work at the Cambridge Institute of Mr. J. S. Steward, Dr. Lapage, and Dr. J. Stewart in the field of parasitology.

Mr. E. L. Taylor, at the Ministry's Laboratory near Weybridge, is giving special attention to stomach worms. In attempting to control gastritis in sheep no success has attended the use of drugs, and therefore the most hopeful method appeared to be to try to prevent the sheep picking up parasites on arable land by the arrangement and moving of the pens. The extent of the infection by worms is all important in determining the amount of injury done by them to sheep. It has been found that infection is at its worst, where the custom is to fold the sheep over the same ground more than once.

The effect of diet on the susceptibility of wether lambs raised free from worm infection is being studied at the Rowett Institute, Aberdeen, in collaboration with the Natural History Department of Aberdeen University and the North of Scotland College of Agriculture. Lambs differently fed, e.g., on full and skimmed milk, are afterwards turned out on pastures heavily infected with *Haemonchus*. Well-fed lambs are found to be much less affected. Dr. D. Robertson of the North of Scotland College found lambs on this sheep-sick land heavily infected with the lesser stomach worm, *Osteragia circumcinta*, known to be resistant to drugs. A small grant has been made by the Agricultural Research Council to enable further investigations to be made on the incidence of this stomach worm on sound and sheep-sick land, and on the systems of management associated with severe infestation. In the North East of Scotland sheep breeding on arable land converted to permanent or semi-permanent pasture has been found to be profitable for the first two or three years only. After that time lambs do not thrive, and may die in large numbers during the autumn. Worm infestation is suspected by the farmers.

Dr. T. W. M. Cameron, now at Macdonald College, Quebec, while he was Lecturer in Helminthology in the University of Edinburgh, investigated the bionomics of the lesser liver fluke of sheep, which he found to be limited in its distribution within Great Britain to the West of Scotland, and to be carried by a land snail, and also the bionomics and possible control of round worms in sheep and pigs. No effective and cheap method of controlling round worms has yet been found. He also made a survey of the parasitic fauna of other animals. Dr. Cameron prepared a memorandum on Helminthology for the Agricultural Research Council, in which he points out that sheep, horses and pigs suffer more from helminthic infections, directly and indirectly, than they do from any other conditions, and that dogs suffer nearly as much from worms as from bacterial and virus diseases. Infection becomes heavier as the concentration of the animal population increases. Several important problems are in urgent need of investigation: the bionomics of the non-parasitic, i.e., the infective stages of helminths, of the parasitic larvae and the adults in the host with their migrations therein, the seasonal and geographical distribution of helminths in its relation to agricultural practice, and methods of control—especially tests on a field scale of applications of present knowledge.

The present lecturer in Helminthology is Dr. D. O. Morgan, formerly of the London School of Hygiene and Tropical Medicine (Institute of Agricultural Parasitology), who proposes to undertake further investigations on the helminths of sheep, pigs, and poultry.

The most important question of future policy in helminthology is the choice between concentrating the work in one place or allowing it to go on in many. Every Institute working at Animal Pathology touches practical helminthological problems, and may need the services of a helminthologist. On the other hand, at the present stage of knowledge, as is recognised in the memorandum of the Ministry of Agriculture and Fisheries, advance may well be best obtained by fundamental studies of the physiology and life history of helminths, which could most effectively be studied in a central Institute. The Agricultural Research Council has appointed a special Committee to consider helminths (see p. 147) and will take the whole problem into consideration in the near future.

Blow Flies

In July, 1932, the Agricultural Research Council examined, at the request of the Scientific Committee of the Economic Advisory Council, a Memorandum by Dr. P. A. Buxton upon the investigations which were being made under his direction in the Department of Entomology of the London School of Hygiene and Tropical Medicine upon the blow flies which attack sheep, especially *Lucilia sericata,* the most widely spread and troublesome of these flies.

The investigations had been carried on during the previous three years by Dr. R. P. Hobson, aided by grants from the Empire Marketing Fund, made on the recommendation of the Dietetics Sub-Committee of the Committee of Civil Research (now the Economic Advisory Council), but assistance from that source was no longer available.

Dr. Buxton pointed out that methods of controlling these pests on any large scale were unknown, and that it had not been discovered why the female fly laid her eggs in the living sheep or how the larva pierces the sheep's skin, though Dr. Hobson's work on the digestive processes of the larva had shown that the larva could not by digestion penetrate the skin. By the use of a technique, devised by Dr. Hobson, for obtaining bacteriologically sterile eggs and rearing the larvae aseptically, further light was being thrown on the part played by bacteria in assisting the growth of the larvae and on the larva's food requirements.

The Agricultural Research Council were in agreement with the Ministry of Agriculture and Fisheries as to the importance of this investigation in its bearing on the control of blow flies in the field, and the Council agreed to make from their own funds a grant of £300 for its continuance during the year ending the 30th September, 1933. Dr. Hobson continued with the aid of the Council's grant his study of the factors influencing the growth of the larva of the common blow-fly, and after some difficulty he succeeded in the experimental infection of mice with blow-fly larvae. During the course of his investigation on the food of the larva, he came to the conclusion that, in the infected sheep, there must be some factor present in the wool, which was not to be found in healthy wool. He subsequently learned that an Australian worker had found that the larvae on " struck " sheep fed on a serous exudate from the skin, and he therefore turned his attention to the growth of larvae on blood and serum. He showed that sterile blood lacked at least three different vitamins, but that bacterial infection of the blood induced growth of the larvae at once.

It was clear that a stage had been reached in this investigation at which it was necessary to transfer it to the field and to have access to sheep. Some slight delay occurred before the necessary arrangements could be made, and the Council therefore made in December last a supplementary grant at the rate of £145 for a period of six months to cover the period from the 1st October, 1933, until the date when it should be possible for Dr. Hobson to go to the University College of North Wales, Bangor, the centre of an important sheep farming area, where he will have advantage of Professor R. G. White's wide knowledge of sheep, and will be associated with Dr. Maldwyn Davies, the Adviser in Agricultural Zoology. Dr. Maldwyn Davies has been surveying the blow fly problem in the field for the past four years, has discovered the districts where attacks by these flies are most prevalent, and has noted the degree of susceptibility to attack, which varies greatly, of different breeds of sheep.

Meanwhile, the Agricultural Research Council is assisting another laboratory investigation in the Department of Entomology of the London School of Hygiene and Tropical Medicine, by Mr. A. C. Evans, who had previously taken part in blow fly researches planned by the Australian Government, into the influence of environment and nutrition upon the biology of the blow fly. The object is to gain further knowledge of those climatic and nutritional factors which appear to limit the activity of blow flies to certain seasons of the year and to make the geographical distribution of blow flies in any district curiously irregular. For the purpose of this investigation the Council have granted a sum not exceeding £300 for the year beginning the 1st October, 1933.

Collaboration has been arranged between Mr. Evans and workers in the Natural History Department at Marishcal College, Aberdeen, who are making a field survey in order to ascertain whether the same species of Lucilia is common to England and Scotland, the time of year when the flies "strike", the breeds of sheep usually affected, the extent of the losses and similar information of practical importance. A grant of £55 has been made by the Council, for the year beginning on the 1st June, 1933, towards the cost of this investigation, which is being carried on under Professor James Ritchie's direction. Mr. F. N. Ratcliffe is responsible for the ecological aspect of the research, and Mr. E. Parry Jones for the entomological work. Facilities for experimental work have been made available on the Rowett Research Institute pastures, which vary widely in type and altitude.

SPECIAL RESEARCHES

In 1932, when it became clear that the agricultural policy of H.M. Government involved a large increase in the animal population, the Animal Diseases Committee of the Agricultural Research Council took into consideration, with the help of other experts not on the Council, including the principal Veterinary officers of the Ministry of Agriculture and Fisheries, the question of what diseases were likely to increase as numbers grew, and which of those diseases appeared to need further survey and investigation. For each such disease or group of diseases they proceeded to appoint a special Committee on which the most eminent appropriate experts were asked to serve. The terms of reference were directed to obtaining from each Committee in the first instance a report on the state of scientific knowledge about the subject under its charge and advice on any additional research work immediately needed.

The Committees appointed were as follows. A list of members is given in Appendix III.

**Committee on Contagious Abortion.* (Committee on *Brucella abortus* infection in Animals and Man.)

Committee on Swine Fever and similar diseases, including enteritis in young pigs.

Committee on Johne's disease in Cattle and Sheep.

Committee on Braxy-like Diseases in Sheep.

Committee on Fowl Paralysis and similar diseases; and on Coccidiosis.

Committee on Helminths of immediate importance in Animal Health.

With regard to Mastitis, the Council obtained from Professor F. C. Minett, the Director of the Research Institute in Animal Pathology, Royal Veterinary College, London, a special report upon the investigations which were being carried on in the Institute. The Council noted that a concentrated attack was being made by the staff of the Institute upon this important disease of cattle in its various forms, and they were satisfied that for the time being additional researches elsewhere need not be planned, and that valuable contacts were being maintained with bacteriologists in the medical field.

The interim reports of most of these special Committees were received after the period covered by this Report, but a summary of the work already done may conveniently be given. In instances where immediate and additional experiment was recommended, the Agricultural Research Council made grants from its own funds, and asked the corresponding Committee of enquiry to become an operative Committee, charged with the task of co-ordinating the work in progress and contemplated. It was decided to invite Directors of the Institutes engaged in research on the various groups of diseases in question to join the Committees at this stage, if they were not already members. The Council's Committees have received valuable assistance from the Imperial Bureau of Animal Health, Weybridge, and some of them also from the Imperial Bureau of Animal Nutrition, Aberdeen. It is hoped that, in next year's Report, the Agricultural Research Council may be able to record definite progress in this part of their work.

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* Appointed in consultation with the Medical Research Council.

Contagious Abortion

The Committee on Contagious Abortion (*Brucella Abortus* Infection in Animals and Man) arranged to work in co-operation with a Scottish Committee on Bovine Abortion which was already in action, and with the Ministry of Health, representatives of both these bodies being co-opted on to the Agricultural Research Council's Committee. The Convenor of the Scottish Committee is Professor T. J. Mackie, a member of the Agricultural Research Council.

Enquiries were made as to the extent of the infection in animals. It was agreed that at present no cheaper method of diagnosis than the agglutination test is available. Work on dead and live vaccines is in progress at various places. An experimental eradication scheme has been drawn up, and will be put into force under the superintendence of Veterinary specialists at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, the Royal Veterinary College, the Department of Veterinary Pathology of Liverpool University, the Veterinary Advisory Officer's Department at the South Eastern Agricultural College, Wye, and the Hannah and Rowett Institutes. It is proposed that the scheme should continue for at least five years and aim at uniformity in all the herds chosen. It is hoped to gain experience more particularly in the control of the disease in herds on farms where complete isolation is impossible. Herds will be examined by the agglutination test at intervals of 2 or 3 months, blood samples will be sent to the laboratories and bacteriological examinations made. Reactors will be separated from non-reactors in conditions to be specified, an explanatory leaflet being given to the owners of the tested herds, and full details of technique to the laboratories. The suspensions of *Br. abortus* for the agglutination test to be used by all the laboratories taking part in the scheme are to be made in the Research Institute in Animal Pathology at the Royal Veterinary College.

With the valuable co-operation of the Ministry of Health and of its medical members, the Council's Committee is endeavouring to obtain more complete and reliable information regarding the importance of *Brucella abortus* infection in relation to the health of human beings. The Ministry has kindly consented to issue a questionnaire and letter to more than 120 bodies who may be able to supply data. Similar information is being obtained and collated in Scotland by the Scottish Committee.

It has been a source of much gratification to the Council to learn since the end of the period with which this Report deals that the Scottish Committee on Contagious Abortion has been successful in attracting additional funds from private sources to supplement the small grants which the Council have made from the limited funds at their disposal. The Highland and Agricultural Society have promised a a grant of £1,000, spread over a period of three years and mainly allocated to research at the Moredun Institute of the Animal Diseases Research Association, under the Scottish Committee's supervision, into methods of immunisation against bovine contagious abortion, on condition that a like sum is collected from other sources. To enable them to fulfil this condition, the Scottish Committee has appealed to Agricultural and Breed Societies and to the Scottish Milk Marketing Board, and up to the present Breed Societies have contributed £45, and the Milk Marketing Board has promised a donation of £600 at the rate of £200 per annum. It is proposed to appoint an additional whole-time research officer at the Moredun Institute. The donation of the Scottish Milk Marketing Board is the first contribution towards expenditure on research to be made by a Marketing Board. The Agricultural Research Council, which is definitely empowered by its Charter to receive gifts and endowments for research, would welcome similar benefactions in aid of other branches of investigation bearing on the problems of agriculture.

Swine Fever

The Committee on Swine Fever, Necrotic Enteritis and Similar Diseases have collected information which is being brought together in two reviews, one on Swine Fever and Necrotic Enteritis, the other on non-specific disorders of young pigs. On these disorders comparatively few publications exist. The Committee propose three lines of research.

As Swine Fever is a notifiable disease, it has been thought best to concentrate research upon it at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at Weybridge, where attention will be specially directed to the best method of securing more satisfactory and accurate diagnosis of the disease. It is hoped also to explore serological methods, to attempt to infect small animals with the disease, so that investigation may proceed more rapidly and economically, to gain further knowledge of its pathology, and finally to endeavour to devise means of immunization. The cost of this additional work at Weybridge, for which a nucleus of at least two whole-time workers will be needed, would be borne not on the Council's funds, but on the Ministry's Vote, if the plans for strengthening the facilities and staff for research at the Veterinary Laboratory are approved. With regard to Swine Erysipelas, which the Committee noted causes in many areas even greater losses than Swine Fever, it is considered that improvement in the methods of immunization should be the chief aim.

It is recommended that further research should be undertaken at the Institute of Animal Pathology, Cambridge, which serves an area subject to severe attacks of this disease, on the biology of the organism and on methods of active immunization, and for this purpoes the Council have agreed to allocate a grant of £450 for a year's work. A junior worker will be added to the staff temporarily for this investigation.

The third line of work planned is on the non-specific disorders, which cause heavy mortality during the first six weeks in the life of young pigs and continued unthriftiness in the survivors, but are of obscure origin. The Committee expressed the opinion that, with increasing density of pig population and increasingly intensive methods of pig rearing, lack of attention to these disorders might " well nullify the efforts to foster home production, and that the question of mortality of young pigs therefore demands early attention." Through Research Institutes, Agricultural Colleges and Pig Recording Associations, and through information from Northern Ireland, the Council's Committee hope, with the help of Veterinary Advisers, to obtain more reliable statistics of mortality; but they feel that, in addition, it will be necessary for an investigator to devote his whole time to a survey in the field of these unspecified disorders throughout the country. He would have his base of operations temporarily at a suitable Institution in the area in which he is working for the time being, but in the critical examination of his material he would call upon the staff of the Ministry's

Veterinary Laboratory for specialized assistance, and he would send reports to that Laboratory for co-ordination and presentation to the Committee. For the salary and travelling expenses of this worker a sum of about £1,000 per annum will be required.

Johne's Disease

The Committee on Johne's Disease reached the conclusion that, as a preliminary to further research, a carefully controlled test of the comparative efficiency of different brands of johnin for the diagnosis of the disease was desirable.

A first test of three brands of johnin and one brand of avian tuberculin was made at the Field Laboratories of the Medical Research Council at Mill Hill, with the generous assistance of the Medical Research Council, who provided accommodation and keep for the animals, of the Sussex Agricultural Society, the Governors of Christ's Hospital and of private owners. Mr. Glover, of the staff of the Cambridge Institute of Animal Pathology, kindly made the necessary injections on the 10 cattle included in the experiment, and interpreted the reactions to the tests as an independent Veterinary worker not directly concerned with the study of this disease. Subsequently post-mortem examinations were made for Johne's disease and tuberculosis by two members of the Council's Committee, in most cases independently. Owing to the fact that some of the animals were not free from tuberculosis, as had been desired, it has been decided to repeat the test, and the Agricultural Research Council has set aside £250 for the purpose.

Braxy

The Committee on Braxy and Braxy-like Diseases of Sheep reports that at present braxy, lamb dysentery and pulpy kidney disease are the most widely recognised anaerobic bacterial diseases of sheep, but that it is probable that in many parts of the country anaerobic bacterial diseases occur, of which the true nature is unknown. Braxy itself is common in many areas in Scotland, Northern England and North Wales. A vaccine against braxy, composed of formalinized whole cultures of the causal micro-organisms, has attained considerable success, but it is desirable that a completely sterile vaccine should be obtained.

Before this can be accomplished research will be needed on the relative immunising values of the more important constituents of the bacterial culture, namely the vegetative bacteria and bacterial spores, and the toxins or modified toxins present in the treated culture. Arrangements will, it is hoped, be made whereby the Committee will be kept informed of the investigations in progress on the various aspects of this problem at the Institute of Animal Pathology, Cambridge, the Moredun Institute, of the Animal Diseases Research Association in Scotland, and the Wellcome Physiological Laboratory, Beckenham.

The Committee state that reports of pulpy kidney disease received from Northumberland, the Eastern Counties and other parts of England, as well as from North Wales and the South West of Scotland show that the disease is not uncommon, though its identity has only been recognised or suspected within recent years.

Such knowledge of the disease as exists in this country points to its relationship with pulpy kidney disease in New Zealand, Australia and Tasmania. The causal micro-organism or micro-organisms belong to the *B. welchii* group, to which also belong the bacteria causing lamb dysentery. As immunization against lamb dysentery has been successful, and the bacterial toxins to be found in cases of that disease and of pulpy kidney are evidently similar, the Council's Committee have not recommended extensive investigations on pulpy kidney disease. They recognise that the multiplicity of the toxins of some bacteria of the *B. welchii* group recently discovered may call for modification of the technique of the preparation of immune sera and vaccines; but the problems involved are already receiving attention at the Cambridge Institute of Animal Pathology and the Wellcome Physiological Research Laboratories, Beckenham, and both those institutions are represented on the Council's Committee on Braxy-like diseases.

It is in the direction of obtaining more authoritative information as to the incidence of infections of sheep by anaerobic bacilli in England and Wales and in Scotland, and in arranging for post-mortem and bacteriological examination of carcases at an early stage after death, so that the causes of mortality may be carefully differentiated, that the Council's Committee see the chief need for further investigation. They therefore propose the appointment of a new research officer to make field investigations in areas of high mortality and to examine the material collected in the field. While engaged on his survey he would be attached to the most conveniently situated Veterinary Laboratory in the area, but he would also require facilities for research at one of the larger Institutes concerned with the study of animal diseases. In considering the problems before them, the Council's Committee were greatly assisted by a full review of the literature on braxy and certain other anaerobic infections of sheep, prepared by the Secretary of the Committee. The Committee will watch the work going on, and think that a field research officer should be appointed when possible at a salary of £400 to £600 and a total annual cost of £1,000 or £1,200. For these purposes the Council have agreed to set aside from their own funds a sum of £1,000 for the first year's work.

Fowl Paralysis

For the Committee on Fowl Paralysis and allied diseases and on Coccidiosis, reviews of the present state of knowledge have been prepared with the assistance of the Imperial Bureau of Animal Health, and it is hoped that suitable arrangements will be made with the Bureau eventually for their publication. The Committee found that field surveys of fowl paralysis had been undertaken from various centres, and the lesions found in affected birds had been studied with the particular object of devising a satisfactory method of differential diagnosis. There appeared to be general agreement that such a condition as fowl paralysis proper (*neuro lymphomatosis*) exists, but it was also clear that paralytic symptoms occur in fowls which are due to several other causes, including coccidiosis. The examination of certain tissues post-mortem by histologists seems to the Committee the only sure method of diagnosis. The Committee are not aware of any experiments which have proved that fowl paralysis is a transmissible disease. Attempts at the Institute of Animal Pathology, Cambridge, to transmit the disease by inoculating tissue emulsions from infected birds, whether by the subcutaneous, intra-cerebral, or intra-neural routes have given negative results, but they are to be repeated on chicks raised from eggs obtained from a flock in which fowl paralysis has never been discovered. If these experiments are successful, further investigation will be made into the nature of the infective organism, and especially with regard to the possibility of its being a filter-passing virus. At the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, which is the centre under the National Poultry Institute scheme for the investigation of poultry diseases, much valuable material is received for diagnosis and advice is sought from all over the country. If the plans for the extension of staff are approved, it is proposed to pay special attention to coccidiosis and fowl paralysis. It is hoped to arrange for a comprehensive survey of fowl paralysis in the field, to be made in the first instance by a special officer; to attempt to ascertain the exact connection between the presence of coccidia and helminths and different forms of paralysis; to endeavour to transmit the disease by inoculation and to ascertain what is the infective agent; and to arrange for pathological examination of all material received. The biochemical aspects of the disease itself would be investigated so that any change in metabolism induced by it might be observed, and, in co-operation with Animal Nutrition Institutes, the relation between diet and the incidence of the disease should be studied.

At the Wellcome Research Laboratories, Beckenham, much attention has been given to the histology of the disease, to attempts to secure its artificial transmission, and to its possible inheritance in certain strains of birds. This work will be continued. In the Departments of Pathology and Bacteriology of Manchester University, the histological work is planned with special reference to the relation which may exist between the nerve lesions found in cases of fowl paralysis and the presence of lymphomatous tumours in other tissues. A small grant at the rate of £100 per annum has been allocated from the Council's funds to supplement a similar donation from private sources for an extension of the investigations at Manchester.

As recommended by their Committee, the Council are making a grant at the rate of £250 per annum to the Molteno Institute for Research in Parasitology at Cambridge, to assist Dr. H. P. Bayon, who also has other funds at his disposal, to continue his work, begun in 1930, upon the diagnosis of fowl paralysis, the cause of the disease, and the influence of nutrition upon its prevention and cure. Encouraging results have been obtained by Dr. Bayon in the past in the treatment of various forms of paralysis of fowls by forcible feeding with greens, and especially with lettuces.

Observations made upon the incidence of fowl paralysis suggest that it is confined to certain breeds of poultry, and the Council's Committee has therefore recommended that carefully controlled breeding experiments of a simple character should be undertaken at Weybridge on land adjoining the Veterinary Laboratory of the Ministry of Agriculture and Fisheries and under the supervision of Dr. W. H. Andrews, the Director of the Laboratory, who would arrange the experiments in association with the Committee. The first object would be to discover by simple experiments, without attempting to cross different strains, whether the disease is inherited.

Clean land would be used, on which would be kept the descendants of certain strains of birds from affected flocks. If the disease appeared among these birds, the next step would be to ascertain, on infected land, whether a state of inherited resistance or susceptibility exists. It is hoped that land and facilities for these experiments may be made available at Weybridge, if funds permit, through the courtesy of the Ministry of Agriculture and Fisheries. In that event no charge would fall upon the Council's own resources.

The Council's Committee formed the opinion that coccidiosis was of even greater economic importance as a disease of poultry than fowl paralysis. Given additional staff, the Ministry of Agriculture and Fisheries hope to allocate a special officer from the Laboratory at Weybridge to visit farms, on which heavy losses are reported, and to collect material and full information. Researches are contemplated on the life histories of the various species of coccidia, on the power of resistance of the parasites to physical and chemical agencies, and to the conditions favouring their survival in the soil and the infection of the host. It is also planned to investigate the influence of diet on the susceptibility and resistance of poultry to infection by coccidia, as well as the general pathology of the disease, the possible influence of breed on infection, and the effectiveness of various curative measures.

Work on many of these problems will also be continued without Government aid at the Wellcome Research Laboratories.

Helminth Diseases

The Committee on Helminths of immediate importance in Animal Health has not yet presented a Report. The Committee is satisfied, however, that there exists no undesirable duplication of effort by the various centres concerned. A list of helminths of chief importance in connection with the health of animals has been drawn up by the Committee, and it has been agreed that it is desirable to discover which nematode is the most common cause of parasitic gastritis, and whether the rare phenomenon of ascarid pueumonia is caused by the adult ascarid. It is not possible to propose further researches in the absence of suitable workers, but it will be necessary sooner or later to promote further investigations on helminthicides (especially carbon tetrachloride) on the normal physiology of nematode worms, on the ecology of the infective larvae of nematodes, and on the feeding habits of nematodes in the gut of animals.

Tuberculosis

Two special Committees dealing with disease in animals have been appointed jointly by the Medical Research Council and the Agricultural Research Council. The Joint Committee on Tuberculosis was appointed in the place of a former Tuberculosis Committee of the Medical Research Council. On the agricultural side, the Joint Committee has so far given particular consideration to the future of the experiments at Cambridge of Professor Buxton and Dr. Stanley Griffith on the degree of immunity conferred on calves by BCG vaccine. Reference is made to these experiments on page 130.

The Joint Committee has also advised the Agricultural Research Council upon applications for assistance from the Council's funds in aid of investigations by Colonel E. C. G. Maddock, late I.M.S., M.D., attached to the National Institute for Research in Dairying at Shinfield, near Reading, on the period during which the bovine tubercle bacillus lives on growing grass, and into the questions whether tuberculosis is conveyed to cattle through grazing on infected land, and if so, how best infectivity through pastures may be prevented. Colonel Maddock's researches had previously been carried on under a Lawrence Studentship awarded by the Royal Society, who also made a grant for the purpose, but this source of aid is no longer available. Colonel Maddock's application was supported by the Ministry of Agriculture and Fisheries, and the Council decided to make a grant in aid of his researches of £200 for the year beginning on the 1st December, 1932, and an additional grant of £326 was made by the Royal College of Physicians of London from a bequest at their disposal for research on tuberculosis. It was understood that the Royal College would probably continue their aid if the Agricultural Research Council did likewise. The investigations made so far were stated by Colonel Maddock, in a recent report to the Council, as showing that, in the cold and wet summer of 1931, virulent bovine tubercle bacilli can be recovered from the soil and dung mixtures after six months' exposure to sun and air, whereas in the average summer of 1932 they were recovered after five months' exposure. The value of the use of controlled concentrations of active chlorine in recovering acid-fast bacteria from grossly contaminated material has been demonstrated. Guinea pigs fed on growing infected grass in 1932 did not develop tuberculosis. In 1933 an experiment was made in feeding guinea pigs on plots which were re-infected monthly. After some four months one guinea pig died and was shown to be infected with tuberculosis. An experiment has been in progress, in the course of which tuberculin tested calves were fed in the open on grass infected monthly, and another group was fed in a shed on cut infected grass.

Attention has also been given by the Joint Committee on Tuberculosis to reported anomalies arising in cattle tested by the double intradermal method, to the desirability of securing the standardisation of tuberculin, and to the advantages of the Cambridge synthetic tuberculin.

Iodine Deficiency and Thyroid Disease

The second Joint Committee appointed by the Medical Research Council and the Agricultural Research Council, at the suggestion of the Medical Research Council, is that on Iodine Deficiency and Thyroid Disease, which is particularly concerned with the incidence of goitre in man and animals in relation to the distribution of iodine in soils, waters and crops. Attempts are being made to devise special methods of iodine analysis by the Committee on the Estimation of Iodine of the Medical Research Council. A sum of £1,000 has been placed at the disposal of the Committee by the Chilian Nitrate Industry.

Foot-and-Mouth Disease

In March, 1933, the Ministry of Agriculture and Fisheries asked the Agricultural Research Council to review the work done under the direction of the Foot-and-Mouth Disease Research Committee of the Ministry, of which Dr. J. A. Arkwright is now Chairman. For some eight years, the major part of the Committee's experiments have been carried on at the Ministry's Isolation Station at Pirbright, and supplementary investigations have been made at the National Institute for Medical Research of the Medical Research Council, at the Lister Institute, and at the Public Health Laboratory of Manchester University. The total cost to the Development Fund has been some £15,000 per annum. In all a sum of £105,383 had been expended upon the Research Committee's programme up to the 31st March, 1932.

The Animal Diseases and Animal Nutrition Committees of the Agricultural Research Council at once appointed a special Sub-Committee to undertake the review for which the Ministry asked. It consisted of Sir Merrik Burrell (Chairman) and Sir Thomas Middleton, members of the Council, with Dr. P. P. Laidlaw and Professor W. W. C. Topley, as additional members.

This Sub-Committee made a thorough examination of the work on Foot-and-Mouth Disease, as set forth in the four

Progress Reports of the Ministry's Committee. The Sub-Committee also visited Pirbright, and held several conferences with Dr. Arkwright, Chairman of the Ministry's Committee, and Dr. Andrews, Director of the Ministry's Veterinary Laboratory at Weybridge, under whose supervision the work at Pirbright is done. The Sub-Committee reported on 1st July, 1933, and, with slight amendments, their Report was adopted by the Animal Diseases and Nutrition Committees and finally by the Agricultural Research Council and was transmitted to the Ministry of Agriculture and Fisheries.

The Sub-Committee expressed cordial appreciation of the work which had been done, and stressed the difficulties which have had to be overcome in order to prevent the accidental spread of infection among the experimental animals or in the district surrounding the Station. The great precautions essential to investigations on this virulent disease have of necessity influenced the rate of progress. When the Ministry's Research Committee was appointed in 1924, knowledge of the disease was, broadly speaking, limited to the fact that it was caused by a filterable virus, and that it was highly infectious. The work of the Research Committee has, in spite of all difficulties, helped to establish the fact of the susceptibility of certain small animals to the disease, and given accurate knowledge of the period of survival of the virus in a variety of different conditions, in the carcasses of dead animals, in certain articles of fodder and on hides and other materials. It has been discovered that the activity of the virus is not destroyed by pickling, and that it may, especially in carcasses stored at low temperatures, remain active for long periods. On this knowledge, it would be possible to base administrative action for the prevention of the spread of the disease.

The discovery by Vallée that the virus of Foot-and-Mouth Disease is not of one type, but of several, has added to the difficulties of the investigation, since each type presents its own problems and needs its own isolation buildings. While, during a period of some years, over 92 per cent. of the strains of virus examined have proved to be of what is called the " O " type, the possible existence of several strains, which would require identification when dealing with outbreaks of disease, would make such an institution as Pirbright necessary for administrative duties alone.

A considerable part of the work has been concerned with problems of immunology, and the Sub-Committee holds that the evidence collected in regard to active and passive immunization in the guinea pig, and to a lesser degree in cattle, forms an important contribution to our knowledge of virus diseases in general and of Foot-and-Mouth Disease in particular, and that, considering the importance of that disease to agriculture, the expense entailed has been fully justified.

In considering the question of future policy the Council's Sub-Committee took account of the argument, which might possibly be advanced, that further investigations on Foot-and-Mouth Disease might be left to some country in which the disease is endemic. The Sub-Committee pointed out that it would be almost impossible to secure in such a country animals for experiment which certainly have not been infected previously in an overt or latent form.

The Sub-Committee next discussed whether the further information likely to be gained would justify the considerable expenditure involved in continuing the investigations. While it seemed unlikely that the future studies in immunisation envisaged by the Ministry's Research Committee would result in a practical alternative to the slaughter policy within a short time, there was, in the view of the Council's Sub-Committee, a reasonable hope that such measures might be devised at a later " but not necessarily remote stage of the enquiry, when the factors determining passive and active immunisation in cattle have been more intensively studied and brought under better control ". Should this prove to the case, the saving in expense to the country would be so large as to compensate for the additional expenditure upon continuing the investigations, even over a long terms of years. On the other hand, to stop the investigations now would render much of the expenditure already incurred relatively unfruitful. In any case, it was considered to be most desirable to maintain a Station where the types of virus causing outbreaks of Foot-and-Mouth Disease in this country can be identified, and for this purpose experiments on cattle or pigs are often required. Finally it was argued that the success obtained in the study of virus diseases, both in man and in animals, in recent years promises well for the future of the Foot-and-Mouth Disease researches, which in their wider aspects are a part of the general attack on problems of virus infection and its control.

Thus the Sub-Committee recommended the continuance of Pirbright on a long-term basis, and pointed out that, even should the work on Foot-and-Mouth Disease be some day suspended, it is probable that the Station would be needed for the study of some other infective or contagious disease, dangerous to man or other animals. In conclusion, the Sub-Committee makes recommendations about the future work to be undertaken and about the best organisation of the Station to cope with it.

Miscellaneous Researches

A brief reference may be made to other miscellaneous research schemes connected with the study of animal diseases for which grants have been made from the Council's funds after consultation with the Agricultural Departments. For the year beginning on the 1st June, 1933, a grant not exceeding £100 was authorised to the Harper Adams Agricultural College, Newport, Shropshire, in aid of an investigation at the National Institute of Poultry Husbandry, which is attached to the College, into the possibility of curing a disease known as " blackhead " in turkeys by the injection of neo-salvarsan. Investigations into this disease are also in progress at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at Weybridge and the Institute of Animal Pathology at Cambridge; though at neither institution, it is understood, are experiments being made in drug-treatment. The Council have arranged that the Ministry's Laboratory shall give general supervision to the scheme of work at the Harper Adams centre. In view of the fact that successful results with the drug have been reported from the field, it appeared highly desirable that these should be checked by controlled scientific experiments, especially as the disease was reported by the Ministry to be one of the greatest troubles with which the turkey breeder is faced. The Veterinary Advisory Officer at the College (Mr. K. D. Downham) will assist with the tests.

Since 1924 fluctuations in the numbers of wild animals, and of outbreaks of disease among them, especially among such rodents as mice, moles, squirrels, rabbits and hares, have been studied in the field by a group of workers from the Department of Zoology and Comparative Anatomy at Oxford under the direction of Mr. Charles Elton, who is now in charge of the Bureau of Animal Population, formed early in 1932. Various aspects of the investigations have been assisted financially from a number of sources; by the Empire Marketing Board, the Ministry of Agriculture and Fisheries, the Department of Scientific and Industrial Research, the Forestry Commission, the New York Zoological Society, the Royal Society, Imperial Chemical Industries Ltd., the Leverhulme Trustees, Liverpool Waterworks, and Messrs. Bryant & Mays. It has been found that the wild animals under observation are subject to outbreaks of disease, and that these outbreaks often occur at intervals and sometimes are associated with the " cycles " in abundance of the animals which have been noted. It is urged by the Director of the

Bureau that the possibility of wild animals " forming reservoirs or carriers of disease must be taken into account ". The Bureau has succeeded in keeping and breeding voles in captivity, and it has found that one species is more susceptible to foot-and-mouth disease than mice or rats. The Bureau's work in relation to the control of rodent pests was also considered by the Ministry of Agriculture and Fisheries to be likely to yield results of importance to agriculture. In view, therefore, of the special interest of the Bureau's investigations on diseases and on the control of agricultural pests, the Council in January, 1933, agreed to make to the University of Oxford a grant from their funds of £150 for one year as from the 1st February, 1933, in aid of the work of the Bureau of Animal Population. The Council expressed the hope that it might be found possible to secure funds from some other source, which would make it possible to add a pathologist to the staff of the Bureau, so that the nature of the epidemics found among wild rodents might be studied; and also that the University might be successful in obtaining elsewhere endowment of a permanent or long term character for the maintenance of the Bureau's activities. In its Report for 1933, the Bureau remarks upon the fact that the grey squirrel is recovering in numbers from its 1930-31 epidemic. Among voles (*Microtus agrestis*) regular fluctuations every three or four years have been observed, and a study of epidemics among voles at Lake Vyrnwy and in Argyll, made in collaboration with Dr. G. M. Findlay, of the Welcome Research Institution, has established a toxoplasma in the brain as the cause. The vole has been found to be susceptible to Rift Valley fever and louping ill as well as to foot-and-mouth disease.

In September, 1932, the Council agreed to make a grant of £300 from their funds for one year from the 1st September, 1932, to Edinburgh University, in aid of an investigation by Dr. J. Yule Bogue, M.R.C.V.S., on the metabolism of sheep, with special reference to changes in the basal metabolic rate shown in sheep suffering from the disease known as " Scrapie." Work done by Dr. J. Russell Greig and Dr. H. Dryerre, of the staff of the Animal Diseases Research Association, had provided evidence of the hyper-sensitivity of the thyroid gland in the course of this disease. It was arranged that Professor A. J. Clark, F.R.S., Head of the Pharmacological Department of the University, should give general supervision to Dr. Yule Bogue's researches, which would be carried on at the Moredun Institute of the Animal Diseases Research Association, under the direction of Dr. Russell Greig. Subsequently the Council made a supplementary grant of £30 for laboratory assistance. Dr. Yule Bogue reports that his experiments showed no demonstrable difference between the metabolic rates of the small number of normal and scrapie sheep under observation, although the disease in the scrapie sheep was so far advanced that all but two died within two months of the first experiment. In the control sheep the average heat production after 5 hours' starvation was 48.67 calories per kilo per 24 hours, and in the scrapie sheep 45.32 calories. After 17 hours' starvation the average heat production of the control sheep was 43.66 calories, and of the scrapie sheep after 24 hours' starvation 47.14 calories. The control sheep for the most part, however, stood up in the respiration chamber, while the scrapie sheep usually lay down. A rise in the metabolic rate occurred after about 14 days in 5 normal sheep, which received 2 milligrams of thyroxin daily.

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VIII. DAIRY RESEARCH

INTRODUCTION

The position of Dairy Research at the beginning of 1931 was summarised in a report by the present Secretary of the Agricultural Research Council, published by the Empire Marketing Board in November of that year. It was there suggested that a study by scientific methods of the whole dairy industry, and the scientific principles underlying it, might properly be included in dairy research. Nevertheless, with limited funds, it was held necessary to restrict Dairy Research Institutes to problems likely either to yield results of fundamental theoretical interest or of practical economic importance, all regarded from the special dairying point of view. The wider aspects of these same problems are better studied in Institutes for research in agriculture, nutrition, pathology or economics, and many of them are described elsewhere in this present Report.

From the dairying point of view, recent researches of most importance include the work which has shown the high nutritive value of young grass, and the need of a balanced ration for cattle containing both vitamins and mineral salts. The necessity for an adequate supply of mineral constituents in pastures, if milk is not to remove some essential constituent of a cow's body and lead to debility or disease, has been studied especially at the Rowett Institute. The vitamin content of milk is higher with cows fed on summer pastures than with stall-fed cows, though it has been shown at Jealott's Hill (see pp. 74, 77, 171) that dried young grass will supply the vitamins required.

Thus the scientific rationing of dairy cows calls for the study of very complex problems, involving not only standards of carbohydrates, digestible proteins, vitamins and mineral salts, but also consideration of the environment, temperature and condition of the animal and its individual idiosyncrasies. Summaries of existing knowledge by Mackintosh, Halnan and others suggest the possibility of a cheapening in the average cost of the necessary food. Moreover, the advocacy by Boutflour of an increased use of concentrates and the development by Hosier of open-air dairying show that new methods of management may prove possible.

The causes of loss of cows from dairy herds have been studied at Shinfield, Bangor, the West of Scotland College and elsewhere. The average length of the milking life of cows works out at the surprisingly low figure of about four years.

The cost of production of "ordinary" and "special" farm milk has been studied among other places at the South Eastern Agricultural College, Wye, at Oxford and at the National Institute for Research in Dairying, Shinfield. Wide differences in total cost are found between different farms. The additional cost of producing special quality (certified) milk appears to be from 3d. to 4d. a gallon.

The physiology, including the genetics, of dairy cattle is studied at many places in many countries. The chemical reactions by which the fat, protein and sugar in milk are synthesized are almost entirely unknown, though attempts have been made to identify the constituents in the blood from which they are derived.* The problem of artificial insemination is being studied in Russia, and, in this country, at Cambridge.

An enormous mass of information, much still unco-ordinated, about the inheritance of high milking qualities is possessed by practical farmers, and exists in the records of Breed Societies and Milk Recording Societies. By selection, great improvement in average yields has been made in our dairy herds,† yet the quality of an individual seems still largely a matter of chance. Indeed, farmers now generally feel that the only sure test of a bull is to wait till the quality of his daughters becomes apparent when they enter the milking herd. Experiments on cattle are necessarily slow, and the use of other animals, such as rabbits, may prove useful in elucidating the general genetics of the milk-yielding factors.

The diseases of dairy stock are dealt with elsewhere in this Report, and need not be referred to here.

Statistical studies of the factors controlling the yield and quality of milk are very voluminous. In this country recent work has been done, especially by Dr. Tocher, at Aberdeen, and by Dr. Cranfield at the Midland College. It must be remembered that milk is a very complex and delicate system, containing water, salts, organic compounds including enzymes and vitamins, in physical and chemical equilibrium. The processes of chemical analysis, such as the addition of re-agents, may upset this equilibrium and alter the nature of the milk. Physical methods, such as the determination of the hydrogen ion concentration, the microscopic examination

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* Recent advances in Dairy Science, N. C. Wright; Agl. Progress, 1929.

† The average yield per head of the dairy herd in England and Wales was as follows :—

1924–25	...	...	416 gallons
1930–31	...	...	462 gallons

The Agricultural Output of England and Wales, 1930–31. Ministry of Agriculture and Fisheries. Cmd. 4605.

of fat globules, and measurements of freezing point and viscosity, are less dangerous in this respect and are therefore particularly valuable.

Owing to laws and official regulations, the determination of the composition of milk has legal and administrative repercussions. A sample of milk containing less than 3 per cent. of fat or less than 8.5 per cent. of other solids is to be presumed for the purposes of the Food and Drugs (Adulteration) Acts, not to be genuine till the contrary is proved. As the milk of a cow varies in composition from time to time and especially between the night and morning milkings, and as some cows persistently give milk of poor quality, the regulations undoubtedly inflict hardship on some honest farmers, while failing to secure to the consumer milk of adequate solid contents.

In 1931 evidence was accumulating to show the value of the measurement of freezing point as a test for the adulteration of milk with water. Freezing point depends on osmotic pressure, and the osmotic pressures of milk and of the blood from which it is derived are closely related and the latter quantity is very constant. Experiments show that genuine milk has a very steady freezing point. Both in Holland and New Zealand, this cryoscopic method had already been adopted as a standard of purity and during the last three years the use of the method has much extended in this country. But Dr. Tocher gives evidence for preferring a test founded on measuring the proportions between the various non-fatty solids in the milk.

The dietetic value of milk is very great. Not only is it the cheapest source of high-grade proteins, but, when fed in right proportions with other foods, it has a specific influence beyond its calorimetric value, especially on growing children and young animals. Children into whose diet raw or pasteurised milk is inserted in place of a caloric equivalent of other food grow much faster both in height and weight than those without it.*

Some experiments have indicated that pasteurised milk is of the same value as raw milk, while it is, if properly handled, safe from pathogenic germs. On the other hand, other experiments have been interpreted to suggest that pasteurising causes physical and chemical changes, which lower the amounts of calcium and phosphorus absorbed. Thus, for example, calves fed on pasteurised milk were found to thrive less well than those fed on raw milk. Much discussion has taken place on this subject, and it is dealt with at length in the recent Report of the Committee of the Economic Advisory Council on Cattle Diseases.*

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* Corry Mann, M.R.C. Report No. 105, 1926; Orr, World's Dairy Congress, 1928; Milk, Department of Health for Scotland, 1930.

The problems underlying the manufacture and storage of dairy products, especially butter and cheese, are being examined at Shinfield and elsewhere, together with faults such as " red spot " in cheese and " oilyness " in butter.

The difficulties which arose during and after the war owing to the enormous quantities of whey ejected from cheese factories led to an investigation by the Ministry of Agriculture and Fisheries and the Royal Agricultural Society of England. In the course of this investigation, Dr. L. Harding invented a new method of extracting lactose (sugar of milk) and producing a by-product—whey paste—of great value for pig feeding. After several changes in ownership, this method is now being extensively used by United Dairies Ltd.

In English towns about 15 gallons of milk a head are used in a year, while in America the consumption is given as 46 gallons, in Denmark 57 gallons and in Switzerland 83 gallons. It is clear there is much room for expansion in this country. Probaby more milk would be drunk as a beverage if it was more usual than at present in England to sell it retail in restaurants in bottles or cartons, in hot weather kept on ice. To pour one's milk from a freshly opened bottle would give a sense of cleanliness and safety.

DAIRY RESEARCH INSTITUTES

National Institute for Research in Dairying, Shinfield

Members of the Dairying, Animal Nutrition and Animal Diseases Committees of the Agricultural Research Council visited the National Institute for Research in Dairying at Shinfield, near Reading, on the 21st July, 1932, and a Sub-Committee further examined the Institute's work on the 9th May, 1933.

The Institute was established at University College, Reading, (now the University of Reading), in 1912. In 1920 a Development Fund grant of £14,000, on the £ for £ principle, was sanctioned in aid of the cost of purchasing for the use of the Institute the Shinfield Manor Estate of about 350 acres. Further grants were made in 1921 for meeting charges for tenant right and legal expenses, and for stocking the farm. In 1922 a grant of £13,000 was approved to cover half the cost of erecting and adapting buildings at Shinfield for the purposes of the Institute. Subsequent grants on the £ for £ basis were made for endowment purposes, especially to match generous gifts to the Institute from Lord Elveden, now the

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* Cmd. 4591.

Earl of Iveagh. The annual maintenance grant from the Development Fund is about £14,000, and the total income approximately £20,000. The Institute is arranged in four Departments, dealing with dairy husbandry, dairy chemistry, dairy bacteriology and dairy physiology. Since the death of Dr. Stenhouse Williams, Dr. H. D. Kay has been appointed Director.

In the Dairy Husbandry Department, Mr. J. Mackintosh (Head of the Department) and Mr. S. Bartlett have been studying statistically the causes of removal of cows from dairy herds. They find the general data on this particular subject obtained from Milk Recording Societies often vague and inconclusive, and feel that an intensive study of a few exactly controlled herds is necessary. They are also studying the problem of inheritance of milk yields, not only as regards quantity but also as regards quality of the milk, and alternatives for milk in calf-rearing. Other investigations in progress under Mr. Mackintosh's direction have been concerned with the growth of young stock carried on over a period of about ten years, with milking machines, and with observations on a typical herd, managed on sound South of England farming principles.

The Physiology Department, which is in charge of Mr. G. L. Peskett, was added to the Institute on a provisional footing in 1928. Some time had to be occupied in equipping it. Dr. S. K. Kon, with the assistance of funds provided by Lord Iveagh, was examining in association with the Physiology and Chemistry Departments the relations between diet and lactation failure, using rats as experimental animals. He is paying attention also to the vitamin content of milk, and finds that vitamin D of butter is not the same chemical entity as D in the form of irradiated ergosterol or that in cod liver oil. There are indications from the experiments on rats that there may be a relation between diet and the colour of the coat.

Messrs. Peskett and S. J. Folley were investigating the chemical nature of good, normal milk, especially as regards the ratio between sodium, diffusible calcium and solids-not-fat to fat; the composition of the blood in relation to that of the milk; and, in collaboration with the Chemical Department, the dietary requirements of lactation.

In the Bacteriology Department, Dr. A. T. R. Mattick was studying several problems in the making of cheese, both as regards starters and ripening. He finds indication that there must be adequate proteolysis before the special lactobacilli can act effectively. The ripening of cheese is probably more enzymatic than bacterial. The Bacteriology

Department was also working on a new steam heated, flash pasteurization plant, which gives promising results. Attention had been given, in collaboration with the Chemistry Department, to various taints in milk and cheese.

The Chemistry Department, of which Captain J. Golding is the head, was collaborating in the examination of "typical" milk, and in investigations on solids-not-fat in milk and the nutrition of the cow in its effect on the vitamin and fat content of the milk. Much attention has been given to checking methods used in milk analysis.

Dr. E. C. V. Mattick has been making nutritional feeding experiments on rats, feeding them exclusively on fresh or pasteurized milk and white flour, and was taking part in the cheese making researches. Mr. W. L. Davies has been enquiring into the effects of traces of metal in producing faulty flavour in dairy products, and into the diacetyl flavour of butter, and has been associated with Mr. J. G. Davis of the Bacteriology Department in much of this work. Mr. Davies, in a study of nitrogen distribution in typical milk, finds that an intimate balance exists between lactose, caseinogen and chlorine. It has been shown that the fat content of milk is actually depressed by the addition of cod liver oil to the ration.

Interesting and promising experiments have been made by Captain Golding, in which sulphuric acid has been replaced by lactic acid whey in the making of ensilage.

Colonel Maddock was experimenting on the survival on pasture of tubercle bacilli. Reference has been made to his work on p. 148 of this Report.

The Council's Sub-Committee, which studied the investigations in progress at the Institute, were well pleased both with the energy of the staff and the work being done. They agreed that additional room was badly needed, the only remedy being more buildings, when funds become available. Some members of the staff have to give a large part of their time to visitors and correspondence. This shows the confidence felt in the Institute by the agricultural community, but the Sub-Committee suggested that an effort should be made to persuade enquirers to make greater use of their County Organiser and his staff, who could pass on difficult questions to the Institute.

The Hannah Dairy Research Institute

The Hannah Dairy Research Institute at Kirkhill, near Ayr, was established in accordance with proposals sanctioned in 1928. The new premises were available for occupation early in 1931. As the result of a gift by Mr. J. M. Hannah to the Department of Agriculture for Scotland of the mansion of Auchincruive and an estate of 850 acres, and of a bequest to the West of Scotland Agricultural College of about £20,600 by the late Mr. Colin Thomson, it was possible to establish the Farm and Dairy School of the College at Auchincruive, and, close at hand, the new Hannah Dairy Research Institute, with its farm of about 120 acres at Kirkhill. A grant of £16,000 on the £ for £ basis was made from the Development Fund for the purpose of establishing the Institute, which is governed by a Council, on which the Secretary of State for Scotland, the University of Glasgow and the West of Scotland College are represented. The maintenance grant to the Institute from the Development Fund sanctioned in 1934-35 was £5,255.

The Institute was visited by a Sub-Committee of the Agricultural Research Council on the 13th June, 1932, and again on the 7th April, 1933, when Professor H. S. Raper assisted those members of the Council who were reviewing the Institute's work. Sections of the Institute are concerned with physiological, biochemical, and pathological problems, and with animal husbandry.

Among the experiments in progress was an examination by the Director, Dr. Norman C. Wright, and Mr. S. Morris of the food requirements of the cow during lactation, by the use of a series of metabolism stalls, which enable the observers to compare the ejecta and the milk as analysed with the food and water taken in. It is found that some types of protein-rich food may be inadequate as precursors of milk proteins by lack of appropriate amino-acids. Lysine appears to be important. Wright and Morris were comparing the composition of local pastures with those studied by Woodman at Cambridge and Imperial Chemical Industries at Jealott's Hill.* On the rich Scottish grass land unmanured plots give as good yields as Woodman's best manured plots at Cambridge. Mr. Morris was also investigating milk fever, to ascertain whether the disease is due to lack of calcium in the blood or to a nitrogenous auto-intoxication.

The late Dr. J. D. Stirling, of whose untimely death the Council have since learned with great regret, working with Dr. J. H. Blackwood, by analysing blood before and after it passes the udder, was trying to determine the precursors of the lactose and proteins in milk. These observers were also interested in the physico-chemical mechanism of milk secretion, and in the chemistry of the synthesis of the non-fatty solids, which is also being examined at Shinfield. Miss Blackwood was also studying the break-down products of milk constituents, especially of casein under peptic and tryptic digestion.

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* In 1933 a local farmer was drying young grass in a plant designed to dry vegetables.

At the Royal Technical College, Glasgow, Dr. A. W. Scott, in association with Dr. Wright, and formerly with Dr. L. A. Allen, has been studying methods of using mik other than by sale as liquid milk or butter or cheese. Dr. Scott has been investigating the physics of the spray-drying of milk, and the solubility of the resultant powder. The team of workers mentioned above were also examining the possible use of dried milk and whey as improvers in bread-making with soft wheats.

Besides these closely co-ordinated researches, the Hannah Institute had employed Dr. L. Jordan, a Veterinary Surgeon paid by the Medical Research Council from a private fund at its disposal. In four years, Mr. Jordan, by regular tuberculin testing and isolation of reactors in 30 herds within a closed area, was able to show that 20 herds were clear of tuberculosis. Eight of the 20 were free of tubercle at the beginning of the experiment and of these 6 remained free throughout. The total proportion of infected cows was reduced from 25 to 9.2 per cent. In collaboration with the Bacteriologists of four large Local Authorities in Scotland, he has taken part in a collective investigation into the percentage of tuberculous infection of the milk supply. The results of this enquiry have recently been published in the form of a Report by the Department of Health for Scotland. Dr. Jordan has also investigated the causes of loss of milk cattle in a large series of recorded herds. Dr. Jordan has now left Scotland and has been replaced by Dr. J. T. Edwards, M.R.C.V.S., formerly of the Royal Veterinary College, London, who is continuing an experimental scheme for the eradication of contagious abortion begun by Dr. Jordan, in association with the Scottish Committee on Bovine Contagious Abortion and the special Committee of the Agricultural Research Council concerned with *Brucella abortus* infection in animals and man.

In 1933 Dr. Wright and Mr. G. R. Howat (a Research Scholar selected by the Agricultural Research Council) were investigating the denaturization (irreversible loss of solubility) in casein, and already obtaining interesting results.

Mr. A. B. Fowler, who is in charge of the Institute farm, was examining the effects on cows of unventilated byres. The only result of a large increase in carbon dioxide seemed to be a rise in the rate of respiration. He is also studying the genetic history of the Ayrshire breed. The results should form a useful comparison with those obtained by Dr. Buchanan Smith in Edinburgh.

Both at the Hannah Institute and at the West of Scotland College investigations into the disease of cattle known as Hoven or Bloat have been in progress and clearly call for the closest co-operation.

The view formed by the representatives of the Agricutural Research Council was that though the work of the Institute is varied, it forms in the main a co-ordinated whole, excellently conducted, and arranged so as not to overlap with that going on at Shinfield or at the Rowett Institute. The staff are capable, keen and interested; they are attacking problems of importance with confidence and by well-judged methods. The finances of the Institute were, however, on a precarious footing, and it has given satisfaction to the Council to learn that it has been found possible to secure an increase in the Government grant.

Dairy Research Department, West of Scotland College of Agriculture

The same Sub-Committee also visited on the 7th April, 1933, the Dairy Research Department of the West of Scotland College of Agriculture at Auchincruive.

Professor R. H. Leitch, continuing his well-known work on the " starters " used in cheese-making, found the great importance of the quality of milk, and especially the slowing action, both on starters and rennet, when the milk is taken from cows suffering from mastitis. Professor Leitch was also carrying on an interesting and valuable investigation into the occurrence in ordinary cheese of putrefactive changes, which he attributes to an organism allied to *B. sporogenes*, introduced into the cheese by contaminated starters. Attention was being given to the cause of the bleaching of coloured cheeses, which is a matter of commercial importance. Professor Leitch had isolated an organism, which under experimental conditions produced bleaching. Professor Leitch's investigations have supplied valuable contributions to our knowledge of the bacteriology of cheese production and the biological processes involved, and his results promise useful practical applications in this branch of the dairy industry.

Dr. A. C. McCandlish in association with Professor Leitch was carrying out feeding experiments to compare roots with A.I.V. silage and with potatoes. These experiments should be comparable with those on the A.I.V. process at the Rowett Institute and Jealott's Hill. The dairy herds of the

South-West of Scotland College are fully recorded, and are being used to investigate " proven sires ". Dr. McCandlish had also in progress an experiment in which groups of calves are fed on diets including raw and pasteurized milk, or on diets changing from raw to pasteurized milk five or ten days after birth, or on diets consisting of raw milk for the first 150 days. The results will need careful statistical examination.

As regards the work of the South-West of Scotland College, it was felt that there was scope for further and detailed bacteriological work. Both in relation to this branch of science, and in relation to dairy research in general, further and closer collaboration between the College and the Hannah Institute, situated as they are on adjoining sites, seems eminently desirable.

IX. AGRICULTURAL ENGINEERING

INTRODUCTION

At a time when there is much discussion about the mechanization of arable farming, the progress of agricultural engineering is of great importance. In some countries considerable provision is made for its study. In 1888 the French " Station d'Essai de Machines " was established at Grignon, and afterwards removed to Paris. It is equipped for carrying out tests which could not well be undertaken by the inventor, manufacturer or user. Other similar stations have been established in Germany, Norway and Sweden, while Denmark and Italy have systems more like that now at work in this country. In the United States of America the University of Nebraska began testing tractors in 1920. Nebraska has played an important part in the development of the tractor, and now tests other agricultural machinery as well.

Before the foundation of the Agricultural Research Council in this country, certain provision for the study of agricultural engineering had been made. The food production campaign of 1917 and 1918 had shown the need of improvement in agricultural machinery and of arrangements for testing it. As a result of the recommendations of three Departmental Committees, a Machinery Testing Committee was established by the Ministry of Agriculture and Fisheries in 1925, and, on the request of the National Farmers' Union and the Association of Agricultural Implement Makers, an Advisory Committee was set up in 1930. Of both these Committees Sir William Dampier was Chairman until 1933, when he was succeeded on the Testing Committee by Professor R. V. Southwell and on the Advisory Committee by Lord Eltisley.

The Machinery Testing Committee has published two Reports. The Advisory Committee on Agricultural Machinery has considered the subject of education in agricultural engineering, and made a survey of the present position.

PRESENT RESEARCHES

Institute for Research in Agricultural Engineering

In 1924 it was decided to establish an Institute for Research in Agricultural Engineering and, after much consideration, to place it at Oxford. Maintenance grants from the Development Fund amounted to about £12,000 in 1931-32 and £10,000 in 1933-34.

Under the first Director, the Institute made an unfortunate start, and the second and present Director, Dr. H. J. Denham, had to face a difficult situation at the beginning of his tenure of office.

The Soils Committee of the Agricultural Research Council co-opted two engineers—Professor E. H. Lamb of the East London College, and Dr. H. J. Gough, Superintendent of the Engineering Department of the National Physical Laboratory. They thus formed an Engineering Sub-Committee which visited Oxford in February, 1932, to inspect the Institute and its trial ground at Hampton Poyle. The following work was then going on:—

(1) Testing of tractors under Mr. S. J. Wright, including the arrangement of tractor trials for the Royal Agricultural Society of England;

(2) Mole draining investigation and demonstrations in co-operation with the Ministry of Agriculture and Fisheries;

(3) Surveys of mechanized farms in co-operation with the Institute of Agricultural Economics, both from the engineering and from the economic point of view;

(4) Physical and chemical problems—the absorption of light in soil suspensions, soil resistance in relation to the design of ploughs, the flow of water in field drains, the electrical heating of soil in frames, and measurements of the moisture contents of grain.

Professor Lamb and Dr. Gough wrote a report on the work of the Institute from the engineering point of view, and expressed their own opinions on the need for such an Institute, and on the programme that it should follow. For their most valuable help the Council desire to offer very cordial thanks. The Committee also conferred with the representatives on the Ministry's Advisory Committee on Agricultural Machinery of the National Farmers' Union and of the Association of Agricultural Implement Makers, with Mr. Dale and Mr. Richardson of the Ministry of Agriculture and Fisheries, and with Dr. Denham, the Director of the Institute.

The outcome of this consideration was the compilation by the Committee of Majority and Minority Reports. Both Reports accepted Professor Lamb's and Dr. Gough's opinion that, for the present, the need was for the application of known engineering knowledge and practice to agriculture rather than for fundamental research in agricultural engineering. Both Reports also expressed the view that it was necessary to provide facilities for the testing of machinery when that testing required elaborate and costly physical or mechanical apparatus, beyond the resources of implement makers. The writers of the Minority Report thought that such facilities could be given by a small department of the National Physical Laboratory at a cost of the order of £2,000 a year. They argued that neither on general grounds of research nor from the demands by farmers nor implement makers was there need for an establishment such as that at Oxford.

The Majority Report, which was signed by the two co-opted engineers, while admitting that the work of the Institute should not extend to physical and chemical investigations on soil, or similar subjects best studied at Rothamsted or other Agricultural Research Stations, nevertheless held that there was scope for an Agricultural Engineering Institute. Agricultural engineering had not kept pace with other branches of engineering, and an Institute which established close relations with both farmers and implement makers could do much to improve both theory and practice. Its functions would also include:—

(*a*) Testing agricultural machinery, especially under the official scheme of the Ministry of Agriculture and Fisheries;

(*b*) Advisory work on agricultural machinery, different members of the staff specializing in different types of implement;

(*c*) The introduction of new and foreign appliances after testing them, and, if necessary, adapting them to British conditions;

(*d*) Assistance for such inventors as brought useful ideas to the notice of the Institute;

(*e*) Surveys of mechanized farms and the supply of authoritative information on the results both technical and economic;

(*f*) Bureau activities, with summaries of the literature on agricultural engineering.

The Majority Report holds that the Oxford Institute is already doing good work under some of these headings, and advises its continuance for a further period with an income of about £10,000, which the Committee considered adequate for carrying on the mechanical and engineering side of its work.

The Majority Report was finally adopted by the Agricultural Research Council and acted on by the Ministry of Agriculture and Fisheries. With the approval of the Development Commission and H.M. Treasury, the Institute is being continued.

Among the more recent activities of the Oxford Institute is the study of the combine harvester as applied to English conditions. This implement, which cuts and threshes corn from the field, has been in use for some years in overseas corn-growing countries, and has been tried by progressive English farmers, such as Mr. G. H. Nevile of Wellingore Hall, Lincoln. Mr. Nevile puts the cost of combine harvesting at about 10s. per acre, and the direct saving by its use at about £1 per acre, with indirect advantages such as less risk of damage by weather. The combine harvester is eminently a machine which can be owned and worked by contractors, who can cut the crops on the smaller farms.

The value of cold storage to meet a glut of fruit is gradually being recognised. Much research on the engineering as well as on the biological problems is being done under the Department of Scientific and Industrial Research at the Low Temperature Research Station at Cambridge and at the Ditton Laboratory at East Malling.

Crop Drying

Much attention has been given in past years to the problem of drying crops artificially—not always with technical or economic success. Nevertheless, the opinion that the problem is worth solving seems fully justified by the importance which it has clearly assumed just recently.

Early in 1932, the Ministry of Agriculture and Fisheries arranged a Conference of those interested in the subject. During the Survey of agricultural research made by the Agricultural Research Council, they became impressed with the importance of crop drying, especially from the point of view of the grassland farmer, and decided to make further enquiries into the subject. To help to start these enquiries, the Ministry of Agriculture and Fisheries prepared an admirable memorandum, setting forth the history and present position of the problem.

The earlier attempts were concerned with the drying of ripe crops—corn in the ear or in grain, hay cut at the late time formerly (indeed still) usual. But the recent work on the nutrient value of young grass and other fodder crops, especially when stimulated by nitrogenous manures, has thrown an altogether new light on the question, and shown that one most important element in the problem is to devise machinery which will handle and dry tender grass, cut when 3 to 6 inches high, without destroying the extremely valuable nutrient qualities which such grass possesses. Thus the problem concerns the vegetable physiologist as well as the chemical engineer.

Young grass, stimulated in growth by nitrogenous manuring and dried at a temperature not high enough to affect injuriously its chemical constitution, has a feeding value weight for weight approximating to that of linseed cake. This has been shown by chemical analyses and by feeding experiments. The young grass has also specific properties which are gradually becoming manifest. At the National Institute for Research in Dairying at Shinfield, an investigation has been made recently on herds of cows which consistently give milk abnormally poor in fatty and non-fatty solids. It was found that the only treatment which raised the quality to normal was to feed the cows on fresh young grass. This experiment should be repeated with young grass when dried. Again, Imperial Chemical Industries have found that the bright yellow substance carotin, found in butter made from the milk of a herd fed on spring or early summer grass stimulated by nitrogenous manures, can be obtained also by feeding them on the same young grass when dried. If this observation is confirmed, and it becomes certain that the natural bright yellow colour in butter and cheese always denotes the presence of the valuable substance carotin, it seems clear that legislation will be necessary to prevent the use of the artificial colouring matters now sometimes employed.

Another possibility is being explored by Imperial Chemical Industries and others—the preservation of young grass as ensilage by the Finnish method known as A.I.V. In this method the loss due to the fermentation of the grass is avoided by the addition of acid as the silo is filled. It is not yet known whether in this form of silage the valuable qualities of young grass are preserved as they are in the dried product.

If, either as silage or dried material, young fodder can be preserved for winter feeding, the British farmer will obtain a valuable home-grown alternative to foreign concentrated feeding stuffs. Moreover, in some of the overseas Dominions, where prolonged drought sometimes makes grazing impossible for lengthy periods, the power of preserving the excess of grass when it comes would enormously improve agricultural prospects. The problem is therefore one of Imperial as well as of local importance. Moreover, in the rapidly developing industry of canning vegetables, the power of preserving the nutritive waste products, otherwise lost, would increase both the profits of the industry and the home supply of animal food.

Even if the experiments on ensilage prove successful, and young fodder can thus be preserved without serious loss of material or destruction of nutrient qualities, the convenience of handling and transporting the dried product will leave it worth while to investigate the best apparatus for drying. The methods are complementary and not alternative.

Many forms of drying plant have been proposed, and a considerable number have been tried during recent years. The method of blowing hot air through a rick of hay or stack of corn did not prove a success. Below a certain critical percentage of initial moisture, drying could be effected, but above that percentage the hot air found channels through the wet material and did not dry it effectively. Thus the idea of drying in the stack had to be given up, and a means found of drying before the material is stored.

In mechanical drying there are two distinct problems—(1) the large-scale process, where the drier is on the factory scale and fodder is brought to it from a big surrounding area, and (2) the small-scale process, in which a smaller plant serves the purposes of a single farmer or of an estate. In the large scale process, it seems likely that one or other of the driers known to chemical engineers could be adapted to grass and other crops; the difficulty is to secure a steady supply of material through a long enough season to make the operations remunerative. In the small-scale process, the problem is to devise a drier, cheap enough for a farmer to buy, and, if possible, light enough for him to move from field to field.

It is impossible in the present merely preliminary statement to describe in detail all the forms of drier which have recently been brought into notice. For quite small quantities of material, an open tray drier may be used. Other types work on the band principle, by which a continuous perforated band carries forward the grass, and currents of air, heated in some form of furnace, or the furnace gases themselves, are forced or drawn by a fan or otherwise through the band and the nutrient material. This general principle is well known in many non-agricultural industries; it may be used both in large-scale and small-scale plant, and there are many varieties in the details of construction and of working. Rotary kilns too are used in many industrial processes and can be adapted to crops. Another type of machine, of which at least one small-scale example is in being, makes the current of hot air itself carry forward the drying material.

Dried grass is already being produced. The Mason process involves a large central plant, worked with a belt conveyor. Those interested state that " it has been in commercial operation in different parts of the United States of America since 1926 ". The Pehrson, a Swedish plant, consists of a rotary kiln, through which hot gases are blown by a fan. The Rema Rosin plant, which uses very hot gases and quick drying, is working in Germany. In Denmark, the Desiccator system works with two cylinders, one inside the other, the hay being passed between them. A plant in Finland draws hot gases through a wind tunnel. Other foreign machines appear to exist.

In England during the 1932 season a drier was at work at the Imperial Chemical Industries Research Station at Jealott's Hill, and Lord Weir also had a larger scale plant of the rotary kiln type running at the Felsted Beet-Sugar factory. There was clearly a considerable amount of quite recent specialised information available, if it could be collected and collated. Moreover, many industrial processes involve drying operations, and it seemed possible that chemical engineers might be able to apply their general knowledge of these operations to the special problem of drying crops more than they had yet done, though the need for care in preserving the special qualities of young plants calls for the collaboration of vegetable physiologists.

The importance of the problem led the Agricultural Research Council to consult the Ministry of Agriculture and Fisheries, and, with their concurrence and that of the Department of Agriculture for Scotland, it was decided that the Agricultural Research Council should call another Conference.

The Conference assembled on 14th March, 1933. As a result of its deliberations, the Agricultural Research Council decided to set up an expert committee to collect such information as is available and to advise the Council whether further experimental investigation is desirable. The Report of the Committee is in course of preparation, and will be summarized in the next Annual Report of the Council.

X. STATISTICAL METHODS

INTRODUCTION

In their survey of the agricultural research going on in this country, the Committees of the Agricultural Research Council have continually been impressed with the fundamental importance of sound statistical methods of experiment. Modern statistical theory is a highly technical and specialised mathematical study, and great advances have been made in it during recent years. Where large numbers of individual plants or animals are involved in an investigation, or many recurrent observations have to be made, or again where numbers are small and several variables are involved, expert statistical knowledge or advice is now essential, both in planning the work and in interpreting its results. The methods used are not confined to agriculture, though for agricultural purposes they may require special adaptation; they can often be applied to other branches of scientific, economic and sociological enquiry. But it happens that field experiments supplied part of the historical basis on which the practical application of statistical theory has been built up, and several of the great advances in the theory or practice were made in England.*

The first scientific field experiments in this country were started by Sir John Lawes at Rothamsted in 1839. Plots of land in parallel strips, not usually more than half an acre each, were treated by various fertilizers, and the crop yields measured. To detect differences in the inherent fertility of different plots, two " control " plots with no special treatment were laid down at opposite ends of the field. If the " control " plots showed little difference in yield, it was assumed that the intervening area was fairly uniform in quality, and the crops on the various strips a true indication of the effects of the fertilizers applied. It was not realized at the time how easily local variations might disturb the results, and the " lay-out " was very different from the complex arrangement now adopted. But the Rothamsted original experiments, carried on on the same plots year after year, are still of value, and the long historical records of crop yields have given new statistical results just recently, when correlated with simultaneous meteorological records.

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* For short historical accounts see Statistical Methods for Research Workers, R.A. Fisher, 4th Ed., London 1932, p. 21; The Contributions of Rothamsted to the Development of the Science of Statistics, R. A. Fisher; and Statistics in Agricultural Research, J. Wishart, Jour. Royal Statistical Society, Jan. 1934. For general theory see as above and also books on Statistics by Udny Yule and A. L. Bowley.

The theory of probability, originally applied to the inductive physical sciences by Bayes (1763), Gauss (1809), Laplace (1820) and others, is now the basis of much of the most recent mathematical physics. It seems first to have been used to investigate biological phenomena from 1835 and onwards by the Belgian astronomer Quetelet, and to medical and insurance data by William Farr, who also put the British Census on a sound footing. Quetelet showed that the chest measurements of Scottish soldiers or the heights of French conscripts vary round the average according to the same laws as are seen in the distribution of bullets round the centre of a target or in the runs of luck at a gaming table. Many men are of heights (or intellects) ranging near the average; the groups of those who are taller or shorter (cleverer or duller) get less as we recede from the mean; giants and dwarfs (geniuses and idiots) are rare.

When the number of observations is large and the distribution symmetrical, we get what is called a normal curve, shaped somewhat like a " cocked-hat ".* Most qualities of plants and animals which can be expressed numerically conform more or less nearly to the normal distribution—the more nearly as the numbers measured are increased.

Of course some phenomena show a greater spread of deviation from the mean than others. The differences in the " spread " of variation in a factor are expressed in terms of the " standard deviation ", which is the square root of a quantity called the " variance ", itself defined as the arithmetic mean of the squares of all deviations, the deviations being measured from the arithmetic mean of the observations. To make results comparable, the standard deviation may be expressed as a percentage of the mean value of the deviations, and is then called the " coefficient of variation ".

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* If the probability of an event occurring be p and the probability of its not occurring be $1 - p = q$, then, if a random sample of n trials is taken, it was shown by Bernoulli that the frequencies with which the event occurs 0, 1, 2.........n, times will be given by the expansion of the binomial $(q + p)^n$.

This is known as a binomial distribution. When n is a large number, mathematical investigation shows that the deviations from the mean lie on a curve given by the equation

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

where σ, the standard deviation, is $\sqrt{pqn}$. We thus get a distribution such that the logarithm of the frequency at any distance x from the centre of the distribution is less than the logarithm of the frequency at the centre by a quantity proportional to x^2. This gives what is called the normal curve of distribution which illustrates Gauss's law of error.

A quantity that does not vary much has a small coefficient of variation and one that varies greatly a high coefficient. For instance, Dr. Tocher of Aberdeen in his study of the "Variations in the Composition of Milk",* found coefficients of variation ranging from 2.8 for the very constant freezing point to 19.76 for the very variable percentage of butter fat.

Theory shows that a deviation greater than the standard deviation may be expected to occur about once in three trials, while the chances are that twice the standard deviation will only be exceeded about once in 22 trials, that is, in rather less than 5 per cent. of the cases. Thus, if the results of an experiment show a difference in two groups of more than twice the standard deviation, the difference is unlikely to be fortuitous, and the odds rise very rapidly as the observed difference increases. It is an accepted convention that differences which exceed twice the standard deviation are regarded as real, or, as it is called "significant".

As long as the distribution of observations is symmetrical about the mean in a normal curve, the problem is fairly simple; but it may be that some disturbing factor produces an unsymmetrical or "skew" curve, and the mathematical theory becomes much more complex.

Again, there are types of distribution quite different from those shown in a normal curve. A variable may not be able to take all values, but may be confined to a particular series, such as whole numbers. As an instance we may name the number of colonies of bacteria on a plate of a culture medium.†

Taking all this into account, a somewhat abstruse mathematical technique was elaborated by Karl Pearson and his school at University College, London, for use in biometric problems. In this work, the most outstanding discovery (1900) was that of the first of the distributions characteristic of modern tests of significance for one measure of discrepancy between observation and hypothesis.‡

Soon afterwards the new methods began to be taken over by the agriculturalists. For instance, Mercer and Hall§ harvested an acre of wheat in 500 small plots, showed how variable the yields might be, and, by working out the standard deviations, found that there was no gain in accuracy by having plots larger than $\frac{1}{40}$ acre.

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* Stationery Office, Edinburgh, 1925.

† Among these discontinuous distributions, of chief importance are the binomial distribution and that given by what is known as Poisson's series.

‡ The sum of the squares of a number of normal variates, written as χ^2, equivalent to ^{n} independent squares, follows the frequency distribution df=Const. $\chi^{n-1}e^{\frac{1}{2}x^2}d\chi$.

§ Jour. Agric. Sci., 1911. 4–107.

Still experiments continued to be carried out in single, or at most in duplicate, plots for each variant, till Dr. E. S. Beaven of Warminster, in conjunction with an investigator who writes himself as " Student," began comparing two varieties of cereals, by loading the first half of a corn drill with one variety and the second half with another, and sowing them in contiguous, parallel strips of 10 to 20 pairs. The standard deviations of the average differences of yield were worked out, and considerable accuracy obtained, especially when a precaution suggested by " Student " was taken to eliminate the effect of any fertility gradient across the strips.

A great change in the technique of experiment was effected at Rothamsted by R. A. Fisher, who, as Dr. Wishart says, " gave to the agricultural research worker an entirely different conception of what a field experiment should be." The method rests on a new mathematical treatment, the analysis of variance, whereby the total variation of heterogeneous material can be analysed into component variations due to different and independent factors. Fisher thus showed that better results could be obtained by working, like Beaven, with several plots of each variant in the experiment, but arranging the plots like a chessboard by chance in a " Randomized Block," or in a " Latin Square," where there are as many replications as treatments, and the randomizing is limited by the condition that each treatment should occur only once in each row of the square, and only once in each column.

Mathematical analysis, carried out chiefly by Fisher and " Student," shows that this arrangement gives a satisfactory measure of variance, and of the differences needed for significance in the results of an experiment.* It has the great advantage that the effects of several factors can be measured in the same experiment. Moreover, it is often important to be able to test any possible connexion between one factor and another. Such connexions when found are expressed in terms of a coefficient of correlation, in which complete correspondence is denoted by unity, complete independence by zero, and partial correlation by intervening fractional numbers.

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* For instance, a table of values of χ^2 (see footnote on page 176) gives us the probability that a value of the size found, or a larger or smaller value, should occur in random samples of the size used.

Randomized Blocks and Latin Squares are now used extensively in field experiments in many places, and are applicable to studies other than those on crops, and to subjects far removed from agriculture.

Enough has been said to confirm the statement that adequate statistical knowledge or advice is needed both in planning an investigation where numbers of subjects for experiment or of observations are involved, and also in interpreting its results. Details of the complicated mathematical theory which has now been built up, and of the special technical treatment necessary for investigating new problems, would be out of place in this Report.

STATISTICS FOR RESEARCH INSTITUTES

In their survey, the Agricultural Research Council found a complete statistical Department at Rothamsted, where Dr. R. A. Fisher has now been succeeded by Mr. F. Yates. There is a Readership in Statistics in the University of Cambridge, founded for Dr. Udny Yule and now held by Dr. Wishart, part of whose salary is found by the School of Agriculture, which has a corresponding claim on his time. Dr. J. F. Tocher gives most valuable assistance to the work of the Rowett Institute at Aberdeen. Mr. T. V. Hoblyn is statistician at East Malling. Mr. F. J. Dudley, statistician at Harper Adams College, deals with the work of branches of the National Poultry Institute at Harper Adams College, at the South-Eastern Agricultural College, Wye, and at the Cheshire School of Agriculture, Reaseheath. Other mathematicians in various Universities give help freely to those working in contiguous or allied Research Institutes.

It is evident that a difficult problem underlies the provision of adequate statistical guidance for all the experimental work going on about the country, and that without it much effort must be wasted. Cambridge and Rothamsted are large enough to need and to carry statisticians of their own. Committees of the Agricultural Research Council have suggested that smaller Institutes, within reasonable distance of each other, might combine to secure the services of a statistician. The Agricultural Research Council is taking the whole subject into consideration, and hopes to be able to make recommendations in the near future.

XI. CONCLUSION

This Report of the Agricultural Research Council, covering the first two years of the Council's existence, will, it is hoped, serve two purposes. It gives a survey of the state of agricultural science in Great Britain in the years 1931 to 1933, and also describes the activities of the Council, with its Committees and Sub-Committees, during that period.

The practice of agriculture is an art and not a science; and modern agriculture, like modern industry in general, has to adapt the new discoveries and inventions of the sciences to its own special ends. But whereas an urban manufacturing industry usually has a fairly definite and limited scope, agriculture is not one trade but many, each complex in itself, and each dependent on varying factors of soil, climate, disease and economic environment. Thus all sciences are now called upon to help man in his age-long struggle to gather the fruits of the earth with as little sweat of his brow as may be.

Not only are the sciences concerned in agriculture developing rapidly and continually adding to agricultural knowledge, but the art of practical farming—the art of making profits from the cultivation of land and the management of stock—is changing almost equally fast. The idea that success in farming depends on long experience handed on from generation to generation can be shown to be erroneous. In the survey of East Anglian farms, carried out by the Economics Branch of the Cambridge School of Agriculture, an enquiry is described in the volume for 1932 wherein farmers occupying over 1,000 farms were arranged in age-groups. An inverse correlation was found to exist between age and success as measured by profit and loss. The younger the age-group the higher were the average profits; the older the farmers the greater the average losses they sustained. For the area examined this is a definite statistical conclusion which cannot be gainsaid. The lesson seems clear. Agriculture is now changing so fast that experience of past methods is less useful than knowledge of new ones and the mental adaptability and courage necessary to try them. This result alone goes a long way to justify expenditure on agricultural education and research.

The survey of agricultural research now going on in the various Research Institutes and elsewhere in this country—a survey which the Agricultural Research Council began in the early weeks of their life—is not yet completed, and the time has not come for a final verdict upon the work. Nevertheless, it is hoped that the present Report will enable those interested to learn generally the present position, though the completion of the survey must be described in future Reports.* The introductions to the various sections, written for the most part by those members of the Council specially conversant with each branch of science, give an account of the present state of knowledge, while the description of the work of the Council and the Committees of the Council reveals the directions in which attempts are now being made in Great Britain to expand that knowledge.

The activities of the Agricultural Research Council, concerned as they must be with the whole field of agricultural research, are meant to assist in guiding the direction of research into the most useful and promising channels, either for fundamental scientific discovery or for the practical and economic application of scientific methods. As appears above, the Council have given continual advice to the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland and the Development Commission. The Council's own limited funds have been used, as is shown in Appendix IV, to start new developments or carry promising researches over a difficult interval till the work is finished or permanent provision has been made for its continuance. Finally, as regards animal diseases, the Council have embarked on a more systematic campaign, in which a series of special committees are examining our knowledge of the diseases most dangerous to an increasing animal population, advising on the further investigations needed to combat them, and, in some cases, arranging for and supervising those investigations.

The termination of the Empire Marketing Board created a difficult position for Institutes in which researches financed by the Board were being carried on. It was impossible for the Treasury to allow all such researches to continue, and the Agricultural Research Council in their advisory capacity had to face the invidious task of discriminating between them. Inevitably the advice did not meet with universal approval, either in this or in other cases when the Council criticised work or, in the financial stringency, advised a curtailment of grants; but this is a natural and expected consequence of one of the normal functions of the Council.

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* Investigations in progress in 1931–32 at research and advisory centres are described fully in the volume of Reports on the work of Agricultural Research Institutes and on certain other agricultural investigations in the United Kingdom: Ministry of Agriculture and Fisheries, Department of Agriculture for Scotland, and Ministry of Agriculture for Northern Ireland. Published by H.M. Stationery Office, 6s. net. New edition for 1932–33 in press.

The amount of wasteful overlapping in the work of the various Research Institutes appears to the Council to be negligible. Even when two Institutes are investigating the same subject, it is usually clear that they have approached it from different angles, and are likely to help each other. Such a conjunction of enquiries is good and not evil. On the other hand, the Council found in several places that different Institutes or sections of Institutes working on the same subject were not collaborating as they should, or even that workers within the same building were carrying out allied enquiries in isolation from each other. The Council have used all their influence to ensure effective consultation and co-operation between individuals or Institutions.

Again, the separation which has existed between some Research Institutes and contiguous Universities and Colleges, to which they are affiliated or have natural relationship, appears to the Council to be unfortunate. Contact between them should be close and continuous. Moreover, the Council uphold the view that most University and College teachers should do research, and that most research workers should do some teaching. The Council are anxious that eventually this opinion should prevail at all centres of work.

In conclusion the Agricultural Research Council hope that enough appears in this Report to show that the work on which they are engaged, if laborious, is full of interest, and that the task—the organisation of agricultural science—which has been entrusted to them justifies the efforts which members of the Council have made to achieve success.

RICHARD CAVENDISH,
Chairman of the Agricultural Research Council.

WM. CECIL DAMPIER,
Secretary of the Council,

6A, Dean's Yard,
Westminster,
London, S.W.1.

1*st August,* 1934.

APPENDIX I

CHARTER CREATING THE MEMBERS OF THE AGRICULTURAL RESEARCH COUNCIL A BODY CORPORATE, UNDER THE STYLE AND TITLE OF "THE AGRICULTURAL RESEARCH COUNCIL."

George the Fifth, by the Grace of God of Great Britain, Ireland and the British Dominions beyond the Seas King, Defender of the Faith, Emperor of India.

To all to whom these Presents shall come, Greeting !

Whereas We were pleased by Our Order in Council dated the 28th day of July, 1930, to appoint the Lord President of the Council, the Minister for Agriculture and Fisheries, the Secretary of State for Home Affairs, the Secretary of State for Scotland and the President of the Board of Education, respectively, for the time being, to be a Committee of Our Privy Council for the organisation and development of agricultural research :

And Whereas the said Committee of Our Privy Council has represented to Us that for the purpose of furthering the objects of the said Committee of Our Council and with a view to facilitating the holding of and dealing with any money provided by Parliament and any other property real or personal available for those objects and with a view, further, to encouraging the making of gifts and bequests in aid of the said objects it is expedient that there should be constituted a body under the name of the Agricultural Research Council which should be responsible to the said Committee of Our Privy Council and should act under its directions, and that the members of the Agricultural Research Council should be created a Body Corporate :

Now, therefore, know ye that We, by virtue of Our Royal Prerogative and of all other powers enabling Us in that behalf, do, of Our special grace, certain knowledge and mere motion by these Presents for Us Our Heirs and Successors *grant, will, direct, ordain, constitute and declare as follows* :—

1. That the first members of the Agricultural Research Council shall be J. A. Arkwright, Esq., F.R.S., M.A., M.D., F.R.C.P. ; Sir Merrik Burrell, Baronet, C.B.E., J.P. ; E. J. Butler, Esq., C.I.E., D.Sc., M.B., F.R.S. ; Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S. ; The Right Honourable Lord Richard Cavendish, C.B., C.M.G. ; Joseph F. Duncan, Esq., Sir John B. Farmer, Knight, M.A., D.Sc., LL.D., F.R.S. ; Sir A. Daniel Hall, K.C.B., LL.D., F.R.S. ; Professor Sir F. Gowland Hopkins, Knight, M.A., M.B., D.Sc., LL.D., F.R.C.P., F.R.S. ; Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E. ; Sir Thomas Middleton, K.C.I.E., K.B.E., C.B., LL.D. ; Spencer Mount, Esq. ; Professor D. M. S. Watson, F.R.S.

2. That all those persons who shall, pursuant to this Our Charter, be members for the time being of the Agricultural Research Council be one Body Corporate under the name of " The Agricultural Research Council," having a perpetual succession and a Common Seal with full power by and in such name :—

(*a*) To sue and be sued ;

(*b*) To enter into contracts or agreements in furtherance of the objects of the said Committee of Our Privy Council ;

(*c*) To accept, hold, and dispose of, money or other personal property in furtherance of the said objects, including sums voted by Parliament for those objects ;

(*d*) To accept any trusts, whether subject to special conditions or not, in furtherance of the said objects ; and

(*e*) Generally to do all other lawful acts whatsoever that may be conducive or incidental to the attainment of the objects for which the said Committee of Our Privy Council has been appointed and the said Agricultural Research Council is hereby established.

3. And We do hereby for Us, Our Heirs and Successors, license, authorise and for ever hereafter enable the Agricultural Research Council to purchase take on lease or otherwise acquire any lands tenements or hereditaments within Our United Kingdom of Great Britain and Northern Ireland not exceeding in the whole the annual value of £50,000 to be determined according to the value thereof at the time when the same are respectively acquired and to hold all or any lands tenements or hereditaments, in perpetuity or on lease or otherwise and from time to time to grant demise alienate or otherwise dispose of the same or any part thereof, or of any interest in or over the same.

4. And We do hereby also for Ourselves, Our Heirs and Successors give and grant Our licence to any person or persons and any Body politic or corporate to assure in perpetuity or otherwise or to demise to or for the benefit of the Agricultural Research Council and lands tenements or hereditaments whatsoever within Our United Kingdom of Great Britain and Northern Ireland within the limits of value aforesaid, hereby nevertheless declaring that it shall not be incumbent upon any person or persons or Body to enquire as to the annual value of the property which may have been previously acquired by the Council.

5. The number of members of the Agricultural Research Council shall on the occurence of a vacancy be reduced to twelve, and thereafter the said Council shall consist of twelve members of whom eight shall at all times be persons appointed after consultation with the President for the time being of the Royal Society, on account of their qualifications in one or other of the basic sciences underlying agriculture and four shall be persons appointed on account of their general experience of and interest in agriculture.

6.—(1) The members of the Agricultural Research Council shall retire in rotation, but any member so retiring shall be eligible for re-appointment.

(2) On the first day of July, 1933, and on the same date in each subsequent year, two members appointed as aforesaid on account of their scientific qualifications, and one other member, shall retire.

(3) The members so to retire shall be determined in such manner as the said Committee of Our Privy Council may from time to time prescribe.

7. Any vacancy, whether casual or otherwise, which may hereafter occur among members of the Agricultural Research Council shall be filled by appointment by the said Committee of Our Privy Council provided, however, that the number of members shall not thereby be increased to more than twelve ; but any person appointed to fill a casual vacancy shall only hold office for the remainder of the period of office of the member in whose place he is appointed.

8. In the appointment of persons to be members of the Agricultural Research Council regard shall be had to the desirability of securing at all times that, so far as possible, one member shall be a person who is also a member of the Medical Research Council, and one other member shall be a person who is also a member of the Advisory Council for Scientific and Industrial Research.

9. The said Committee of Our Privy Council shall, after consultation with the members of the Agricultural Research Council and the

President of the Royal Society, appoint one of the members of the Agricultural Research Council to be Chairman thereof.

10. The Agricultural Research Council shall with the approval of the Lord President of the Council and after consultation with the President of the Royal Society appoint a Secretary of the Council and may pay to him such remuneration as the said Committee of Our Privy Council may, with the approval of the Lords Commissioners of Our Treasury, from time to time determine.

11. The Agricultural Research Council may also appoint such other officers and servants as they think fit, but the number of such officers and servants and their remuneration shall be subject to the approval of the said Committee of Our Privy Council and of the Lords Commissioners of Our Treasury.

12. There may be paid as honoraria to members of the Agricultural Research Council such sums as the said Committee of Our Privy Council may, with the approval of the Lords Commissioners of Our Treasury, from time to time direct, and the Council may also expend such sums for the administrative purposes of the Council, including travelling expenses and subsistence allowances for members and staff, as the said Committee of Our Privy Council may with the like approval from time to time determine.

13. The Agricultural Research Council shall at all times be responsible to and shall, subject to the provisions of this Our Charter, comply with such directions as may from time to time be given to them by the said Committee of Our Privy Council.

14. All property for the time being vested in the Agricultural Research Council or the proceeds of sale thereof shall be held by them for the purposes of the Council and in such manner as the said Committee of Our Privy Council, subject to the provisions of this Our Charter or of any trust affecting such property, may approve.

15. The accounts of the Agricultural Research Council shall be made up for each financial year ending the 31st day of March and shall be prepared and audited in such manner as the Lords Commissioners of Our Treasury may from time to time direct.

16. The Agricultural Research Council shall in every year prepare and submit a report to the said Committee of Our Privy Council.

17. It shall be lawful for Us, Our Heirs and Successors by Supplemental Charter to add to amend or repeal the provisions of this Our Charter or any of them.

In Witness whereof We have caused these Our Letters to be made Patent.

Witness Ourself at Westminster the twenty-third day of July in the twenty-second year of Our Reign.

By Warrant under the King's Sign Manual.

SUPPLEMENTAL CHARTER GRANTED TO "THE AGRICULTURAL RESEARCH COUNCIL"

George the Fifth, by the Grace of God of Great Britain, Ireland and the British Dominions beyond the Seas King, Defender of the Faith, Emperor of India.

To all to whom these Presents shall come, Greeting!

Whereas in the year of our Lord 1931 by Royal Charter dated the Twenty-third day of July, 1931, in the Twenty-second year of Our Reign (hereinafter referred to as "the Original Charter") We constituted the persons named therein and the persons who should pursuant thereto be members for the time being of the Agricultural Research Council one Body Corporate under the name of "The Agricultural Research Council":

And Whereas it was provided by the Original Charter that the number of members of the Agricultural Research Council should on the occurrence of a vacancy be reduced to twelve and that thereafter the said Council should consist of twelve members appointed as therein provided by the Committee of Our Privy Council for the organisation and development of agricultural research:

And Whereas it has been represented to Us that it is expedient that the number of persons who may for the time being be members of the Agricultural Research Council should be varied in manner hereinafter appearing:

Now therefore know ye that We, by virtue of Our Royal Prerogative and of all other powers enabling Us in that behalf, do of Our special Grace, certain knowledge and mere motion by these Presents for Us, Our Heirs and Successors, grant, will, direct, ordain, constitute and declare as follows:—

1. The Original Charter shall be altered and extended in the manner hereinafter mentioned and shall henceforth be read, construed, and take effect as if the said alterations and additions had originally been contained therein, but otherwise the Original Charter shall remain in full force and effect.

2. For the provisions of Article V of the Original Charter shall be substituted the following:—"The said Committee of Our Privy Council may appoint further persons to be members of the Agricultural Research Council so however that the members of that Council shall not thereby be increased to more than fifteen and The Agricultural Research Council shall at all times consist of not more than fifteen nor less than twelve members of whom not less than four nor more than five shall be persons appointed on account of their general experience of and interest in agriculture and the remainder shall be persons appointed after consultation with the President for the time being of the Royal Society, on account of their qualifications in one or other of the basic sciences underlying agriculture."

3. In Article VII of the Original Charter, for the word "twelve" substitute the word "fifteen."

In Witness whereof We have caused these Our Letters to be made Patent.

Witness Ourself at Westminster the Twenty-fourth day of March in the Twenty-fourth year of Our Reign.

By Warrant under The King's Sign Manual.

APPENDIX II

Provisional Note on Administrative Arrangements given by the Right Honourable Lord Parmoor, then Lord President of the Council, to the Agricultural Research Council at its inception, as a guide in its relations with the Agricultural Departments, the Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland, and with the Development Commission

1. The existing general relationship of the Agricultural Departments with Agricultural Research Institutes, University Departments of Agriculture and Agricultural Colleges will continue unchanged, and grants will be made by the Agricultural Departments to these Institutions as hitherto. But as regards research grants the Agricultural Departments will provide the Agricultural Research Council with all information at their disposal and will receive its criticism or advice. In particular, the research programmes of the Institutes and University Departments will be referred by the Agricultural Departments to the Council (together with estimates of cost) so that the Council may furnish the Departments with its comments and advice before their proposals are submitted to the Treasury.

2. The Council will consult the Minister of Agriculture and the Secretary of State for Scotland with regard to proposals initiated by the Council affecting the Institutions for which the Agricultural Departments are responsible.

3. Expenditure for research services hitherto administered by the Agricultural Departments and borne on their Votes, will so remain (unless and until the services are discontinued) together with any expenditure hereafter authorised for expansion of those services.

4. Save as noted at 8 below, detailed Treasury control of expenditure will remain.

5. Parliamentary responsibility for agricultural research will remain with the Ministers responsible for agriculture.

6. The dividing line now drawn between expenditure financed direct by the Agricultural Departments and expenditure financed by these Departments by means of grants from the Development Fund will be retained.

7. In addition to advising the Agricultural Departments as noted in paragraph 1 above, the Council will act as the scientific advisers of the Development Commissioners on schemes of agricultural research, the Development Commissioners reporting as heretofore to the Treasury when they desire to recommend expenditure.

8. £5,000 will be provided in 1931 for the Research Council from the Development Fund, together with such sum not exceeding £2,000 as may be required for the payment of honoraria and expenses approved by the Treasury. The Research Council will decide on their own authority in regard to expenditure from the £5,000 which will be paid to them with Treasury approval on the recommendation of the Development Commission. Any savings on the £5,000 will be non-surrenderable.

9. Other administrative points which may arise later will be settled inter-departmentally after consideration of the views of all concerned.

APPENDIX III

COMMITTEES OF THE AGRICULTURAL RESEARCH COUNCIL

STANDING COMMITTEES

Soils and Plant Nutrition

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir John B. Farmer, M.A., D.Sc., LL.D., F.R.S.
Sir A. Daniel Hall, K.C.B., LL.D., F.R.S.
Spencer W. Mount.

Plant Physiology, Breeding and Disease

Sir A. Daniel Hall, K.C.B., LL.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.
Joseph F. Duncan.
Sir John Farmer, M.A., D.Sc., LL.D., F.R.S.
J. C. F. Fryer, O.B.E., M.A.
Spencer W. Mount.

Animal Diseases

Sir Merrik Burrell, Bart., C.B.E., J.P. (*Chairman*).
W. H. Andrews, D.Sc., M.R.C.V.S.
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
P. P. Laidlaw, Ch.B., F.R.C.P., F.R.S.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
*R. E. Montgomery, M.R.C.V.S.
Major-General Sir John Moore, K.C.M.G., C.B., F.R.C.V.S.
Professor W. W. C. Topley, M.A., M.D., F.R.S.

Animal Nutrition and Breeding

Professor Sir Frederick Gowland Hopkins, D.Sc., F.R.C.P., P.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
P. P. Laidlaw, Ch.B., F.R.C.P., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D.
Professor W. W. C. Topley, M.A., M.D., F.R.S.
Professor D. M. S. Watson, F.R.S.

Dairying and Animal Products

Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
Professor D. M. S. Watson, F.R.S.

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* Died June, 1932.

Economics

Joseph F. Duncan (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir A. Daniel Hall, K.C.B., LL.D., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D.
Professor F. W. Ogilvie, M.A.

OTHER COMMITTEES

Estimates and Programmes of Research Institutes

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
*E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.
Sir John B. Farmer, M.A., D.Sc., LL.D., F.R.S.
Professor D. M. S. Watson, F.R.S.
*Spencer W. Mount. (For English Research Institutes only.)
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
Joseph F. Duncan.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
(For Scottish Research Institutes only.)

Scholarships

Sir A. Daniel Hall, K.C.B., LL.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.
Sir William Cecil Dampier, Sc.D., F.R.S.
Sir John B. Farmer, M.A., D.Sc., LL.D., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D.
Professor D. M. S. Watson, F.R.S.

Schemes formerly aided from the Empire Marketing Fund†

The Right Honourable Lord Richard Cavendish, C.B., C.M.G. (*Chairman*).
E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.
Joseph F. Duncan.
Sir John B. Farmer, M.A., D.Sc., LL.D., F.R.S.
Sir A. Daniel Hall, K.C.B., LL.D., F.R.S.
Professor Sir Frederick Gowland Hopkins, D.Sc., F.R.C.P., P.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D.
Professor D. M. S. Watson, F.R.S.

COMMITTEES FOR THE INVESTIGATION OF SPECIAL SUBJECTS

The Preservation of Grass and other Fodder Crops

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*).
Thomson Close.
H. J. Denham, M.A., D.Sc.
H. J. Gough, M.B.E., D.Sc., F.R.S.
Leonard Harding, Ph.D., M.I.Chem.E.
H. J. Page, M.B.E., B.Sc., F.I.C.
Professor R. G. Stapledon, C.B.E., M.A.
J. G. Stewart, B.Sc.
Professor J. A. Scott Watson, M.C., M.A.
H. E. Woodman, M.A., D.Sc.

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* Appointed after the close of the period covered by the present Report.

† Set up after the close of the period covered by the present Report.

Iodine Deficiency and Thyroid Disease

(*Jointly with the Medical Research Council.*)

*Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S. (*Chairman*).
Professor George Barger, M.A., D.Sc., F.R.S.
H. H. Green, D.Sc.
Professor C. R. Harington, D.Sc., F.R.S.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
†J. B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S.
A. W. Spence, M.B., M.R.C.P. (*Secretary*).

SPECIAL COMMITTEES TO ENQUIRE INTO THE STATE OF KNOWLEDGE REGARDING THE MOST IMPORTANT AND MOST DANGEROUS ANIMAL DISEASES AND THE WORK IN PROGRESS UPON THEM, AND TO CO-ORDINATE FURTHER RESEARCH

Braxy-like Diseases in Sheep

Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E. (*Chairman*).
T. J. Bosworth, B.Sc., M.R.C.V.S., D.V.S.M.
‡Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
‡Major T. Dalling, M.R.C.V.S.
Professor S. H. Gaiger, F.R.C.V.S.
Professor J. Russell Greig, Ph.D., M.R.C.V.S.
A. D. McEwen, B.Sc., M.R.C.V.S. (*Secretary*).

Contagious Abortion§

(*Brucelea abortus infection in Animals and Man.*)

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
W. Horner Andrews, D.Sc., M.R.C.V.S.
‡Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
Sir Weldon Dalrymple-Champneys, Bart., D.M., M.R.C.P.
‡Capt. T. M. Doyle, F.R.C.V.S., D.V.S.M.
‡Professor S. H. Gaiger, F.R.C.V.S.
Professor R. G. Linton, Ph.D.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
A. D. McEwen, B.Sc., M.R.C.V.S.
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S.
W. A. Pool, M.R.C.V.S. (*Secretary*).
J. Smith, M.D., D.Sc.
Professor G. S. Wilson, M.D., M.R.C.V.S., D.P.H.

Fowl Paralysis and Similar Diseases and Coccidiosis

Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S. (*Chairman*).
T. Dalling, M.R.C.V.S.
N. Dobson, B.Sc., M.R.C.V.S.
P. A. Francis, O.B.E.
R. E. Glover, B.Sc., M.R.C.V.S.
H. H. Green, D.Sc.
Professor D. Keilin, Sc.D., F.R.S.
C. A. McGaughey, M.R.C.V.S., D.V.S.M. (*Secretary*).
‡J. E. Wilson, B.Sc., M.R.C.V.S.

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* Retired after the close of the period covered by the present Report.

† Appointed Chairman in place of Professor Cathcart, after the close of the period covered by the present Report.

‡ Appointed after the close of the period covered by the present Report.

§ This Committee was appointed in consultation with the Medical Research Council and works in association with the Scottish Committee on Bovine Contagious Abortion, of which Professor T. J. Mackie is Convener.

Helminths of Immediate Importance in Animal Health

Professor D. M. S. Watson, F.R.S. (*Chairman*).
C. Lapage, M.B., Ch.B., M.Sc.
Professor R. T. Leiper, M.D., D.Sc., F.R.S.
*D. O. Morgan, M.Sc., Ph.D. (*Secretary*).
†W. Nicholl, M.A., D.Sc., M.D.
J. B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S.
E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.
*Professor W. W. C. Topley, M.A., M.D., F.R.S.

Johne's Disease in Cattle and Sheep

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
G. W. Dunkin, M.R.C.V.S., D.V.H.
Professor S. H. Gaiger, F.R.C.V.S.
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S. (*Secretary*).

Swine Fever and Similar Diseases including Enteritis in Young Pigs

W. Horner Andrews, D.Sc., M.R.C.V.S. (*Chairman*).
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
C. Crowther, M.A., Ph.D.
Captain T. M. Doyle, F.R.C.V.S., D.V.S.M.
H. H. Green, D.Sc. (*Secretary*).
*P. P. Laidlaw, Ch.B., F.R.C.P., F.R.S.
J. B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S.
Captain W. G. Wragg, M.R.C.V.S.

Tuberculosis

(*Jointly with the Medical Research Council*)

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H. (*Joint Secretary*).
Professor S. L. Cummins, C.B., C.M.G.
Capt. S. R. Douglas, M.R.C.S., F.R.S., late I.M.S.
Dr. Alison Glover, O.B.E., M.D., F.R.C.P. (*Joint Secretary*).
A. Stanley Griffith, M.D.
A. S. MacNalty, D.M., F.R.C.P.
Major-General Sir John Moore, K.C.M.G., C.B., F.R.C.V.S.

Members of Sub-Committees, not Members of the Council or its Committees, who served during the period covered by the present Report

Professor Sir Rowland H. Biffen, M.A., F.R.S.
Professor C. A. Lovatt Evans, D.Sc., F.R.S.
Professor J. B. S. Haldane, M.A., F.R.S.
H. Hunter, D.Sc.
Professor E. H. Lamb, D.S.C., D.Sc., A.M.Inst.C.E., M.I.Mech.E.
Professor H. A. D. Neville, M.A., B.Sc., F.I.C.
G. H. Pethybridge, M.A., B.Sc., Ph.D.
Professor R. C. Punnett, M.A., F.R.S.
Professor M. S. Raper, C.B.E., D.Sc., F.R.S.
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.
J. Wishart, M.A., D.Sc.

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* Appointed after the close of the period covered by the present report.

† Retired, 1933.

APPENDIX IV

GRANTS SANCTIONED BY THE AGRICULTURAL RESEARCH COUNCIL DURING THE PERIOD JULY, 1931 — 30th SEPTEMBER 1933 FOR PAYMENT FROM THE FUNDS OF THE COUNCIL

Plant Diseases

April 1932 ...	East Malling Research Station	Investigations into the methods of control of the Raspberry and Loganberry beetle by Mr. W. Steer	£200 spread over two years from 1st Oct. 1932.
July 1932 ...	School of Rural Economy, Oxford	Investigations into measures for the control of apple mildew by Dr. R. C. Woodward	£300 for nine months to 30th Sept. 1933
October 1932	University College, Hull	Investigations into the distribution by wind of various insects, particularly agricultural pests by Mr. P. S. Milne	£92 for eleven months ending 30th Sept. 1933.

Plant Breeding

October 1931	John Innes Horticultural Institution	Systematic investigations of the Genetics, Cytology and Taxonomy of the Genus Rosa by Dr. C. C. Hurst	£400 for one year from 1st Oct. 1931
July 1932 ...	John Innes Horticultural Institution	Cytological work, Breeding Experiments, Pyrus, Prunus and Rubus	£250 for one year from 1st Oct. 1932
January 1933	John Innes Horticultural Institution	Systematic Investigation of the Genetics, Cytology and Taxonomy of the Genus Rosa by Dr. C. C. Hurst	£300 for one year from 1st Oct. 1932
January 1933	John Innes Horticultural Institution	Research on the varieties of the British Flora at Potterne, Wiltshire, by Mr. E. M. Marsden-Jones	£100 for one year from 1st March 1933
May 1933 ...	Welsh Plant Breeding Station, Aberystwyth	Travelling Fellowship to enable Mr. G. Evans to visit Germany, Austria and Hungary in June 1933, to study seed production in those countries	£50

Plants (Misc.)

April 1932 ...	University of Bristol	Experiments on the intensive stocking of grasslands	£200 for one year from 1st May 1932
April 1933 ...	University of Bristol	Experiments on the intensive stocking of grasslands	£200 for one year from 1st May 1933
April 1933 ...	Bristol University	Travelling Research Fellowship to enable Mr. F. Hirst (Director of the Chipping Campden Fruit and Vegetable Preservation Station) to visit the United States of America in order to study the present position of research on Canning problems in that country	£125

Animal Diseases

January 1932	University of Edinburgh, Pharmacological Laboratory	Research by Dr. Yule Bogue on Scrapie and the Metabolism of Sheep	£300 for one year from 1st Sept. 1932 £30, supplementary grant for Laboratory Assistance
July 1932 ...	London School of Hygiene and Tropical Medicine	Research work on Blow Flies which attack Sheep by Mr. R. P. Hobson	£300 for one year from 1st Oct. 1932
July 1932 ...	Institute of Animal Pathology, Royal Veterinary College, Camden Town	Experiments at Mill Hill on Johne's Disease, conducted by the Council's Committee.	£13
October 1932	National Institute for Research in Dairying, Reading	Research into Bovine Tuberculosis by Col. E. C. G. Maddock	£200 for one year from 1st Dec. 1932
October 1932	Imperial Bureau of Animal Health, New Haw, Weybridge	Preparation of special bibliographies and abstracts for Committees of the Council	£250 for one year from 1st Feb. 1933
January 1933	Oxford University, Bureau of Animal Population	Investigations into the fluctuations in numbers and diseases among wild rodents in Great Britain	£150 for one year from 1st Feb. 1933

May 1933	...	Royal Veterinary College, Camden Town £120 Veterinary Department, South Eastern Agricultural College, Wye £250 Department of Veterinary Pathology, Liverpool University £60 Hannah Dairy Research Institute £275 Rowett Research Institute £75 Animal Diseases Research Association £170 Do. for administrative expenses £50	For work under the co-ordination of the Council's Committee on Contagious Abortion	£1,000
May 1933	...	Rowett Research Institute, Bucksburn, Aberdeen	Investigations into the intestinal parasites of Sheep	£185 for one year from 1st Oct. 1933
May 1933	...	Aberdeen University, Natural History Department	Investigations into the Blow Flies of Sheep, to be carried out in co-operation with the Rowett Research Institute	£55 for one year from 1st June 1933
May 1933	...	Harper Adams Agricultural College, Newport, Salop	Investigations into the possibilities of curing Blackhead Disease in Turkeys by the use of Neo Salvarsan	£100 for one year from 1st June 1933
July 1933	...	London School of Hygiene and Tropical Medicine	Research on Blow Flies which attack Sheep by Mr. A. C. Evans	£300 for one year from 1st Oct. 1933
		Animal Breeding		
April 1933	...	Edinburgh University, Institute of Animal Genetics	Researches on Wool Problems	£205 for six months to 30th Sept. 1933
		Animal Nutrition		
July 1933	...	School of Rural Economy, Oxford	Investigation into problems of Sheep Nutrition	£100 for one year from 1st Oct. 1933

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COMMITTEE OF THE PRIVY COUNCIL FOR
THE ORGANISATION AND DEVELOPMENT OF
AGRICULTURAL RESEARCH

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL FOR THE PERIOD
October 1933—September 1935

Presented by the Lord President of the Council to Parliament
by Command of His Majesty
July 1936

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REPORT OF THE

COMMITTEE OF THE PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH

For the period
October 1933 to September 1935

TO THE KING'S MOST EXCELLENT MAJESTY IN COUNCIL.

MAY IT PLEASE YOUR MAJESTY,

We, the Lords of the Committee for the Organisation and Development of Agricultural Research of Your Majesty's Privy Council, appointed by His late Majesty's Order in Council dated the 28th day of July, 1930, humbly submit to Your Majesty a second Report of our proceedings, covering the two years from the 1st day of October, 1933, to the 30th day of September, 1935.

During the two years under review the Committee has received eighteen comprehensive Reports of the Agricultural Research Council, of its Committees and Sub-Committees. The Committee of Privy Council met on the 6th February, 1934, and on the 14th February, 1935, when these Reports were amplified by the Secretary, and a statement was given of the past and current work of the Agricultural Research Council.

An amendment of the Charter of the Agricultural Research Council, providing that the number of members should be not less than twelve or more than fifteen, was approved for submission to His late Majesty in Council. As stated in the first Report, this increase in numbers was considered necessary to cover the many subjects involved in the work of the Agricultural Research Council.

On the 24th March, 1934, His Majesty was graciously pleased to issue a Warrant for a Supplementary Charter, carrying this amendment into effect. The Charter and Supplemental Charter were reprinted in the Council's first Report (Cmd. 4718).

As regards the rota of retirement of the members of the Agricultural Research Council, it was directed by the Committee of Privy Council that members who retire shall be eligible for immediate re-appointment until all the original members shall have retired once, the order of retirement to be determined by lot at a meeting of the Agricultural Research Council. The members of the Agricultural Research Council who retired by lot in 1933, 1934 and 1935 were re-appointed by the Committee.

The estimates of the Agricultural Research Council for the financial year 1934-35, amounting to £3,705 for administrative expenses and £6,000 for the promotion of research, were approved by the Committee and by the Lords Commissioners of Your Majesty's Treasury. Provision was made accordingly by Parliament in the Vote for Scientific Investigation, etc. (Class IV, 9) with an equivalent appropriation-in-aid from the Development Fund. For 1935-36 a provision of £20,000 by way of grant in aid, of which £4,475 was for administrative expenses, was sanctioned. In the progress reports on the work of the Agricultural Research Council submitted to the Committee by the Secretary, an account was given of the research work undertaken in State-aided institutions by means of the much larger provision made on the Votes of the Agricultural Departments. For the financial years 1933-34 and 1934-35 sums of £310,932 and £329,695 were included for research and advisory work in the estimates of the Agricultural Departments with appropriations-in-aid from the Development Fund.

The Agricultural Research Council advises the Departments and the Development Commission with regard to the whole of the work aided by means of grants made from these sums for research and the training of research workers.

As explained in the first Report of the Committee, a Provisional Note on Administrative Arrangements was given to the Agricultural Research Council on its inception by the Right Honourable Lord Parmoor, then Lord President of the Council. The purpose of the Note was to define the relations between the Agricultural Research Council on the one hand and the Treasury, the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland and the Development Commission on the other.

Certain differences of interpretation of clauses of the Note have caused difficulties from time to time. These difficulties were accentuated when the Council, on the advice of a majority of their own Committee on *Brucella abortus* Infection in Animals and Man, wished to carry out large scale work on contagious abortion at a farm centre under their own control. In conformity with the recommendation of the Committee on Cattle Diseases of the Economic Advisory Council* that the Committee on *Brucella abortus* Infection should be given every possible facility through the Agricultural Research Council for the early completion of their programme, the Agricultural Research Council had asked their Committee for recommendations in regard to the development of their work. At the meeting of the Committee of Privy Council on the 14th February, 1935, it was resolved that such large scale work was needed, though a decision about the method of carrying it out was postponed for future consideration. It was also agreed that the administrative problems involved and their relation to the Provisional Note should be discussed in the near future.

By direction of the Right Honourable Stanley Baldwin, then Lord President, this question was first discussed between officials of the Agricultural Research Council and those of the Agricultural Departments, and subsequently was again taken into consideration by the Ministers. Finally, on his appointment as Lord President, the Right Honourable J. Ramsay MacDonald summoned a Conference at the House of Commons on the 25th June, 1935, at which the Secretary of State for Scotland, the Minister of Agriculture and Fisheries and representatives of the Agricultural Research Council were present. Principles of revision were then settled, and details were arranged at a meeting at the Treasury on the 11th July. The revised Provisional Note, as set forth in Appendix I, was approved by the Agricultural Research Council on the 17th July, and finally by the Committee of Privy Council. It accepts the view that the Agricultural Research Council can carry on agricultural research themselves and employ scientific and other staffs for that purpose (subject to normal Treasury control), definitely stating that they may do so at centres of their own or elsewhere. If the work is to be done at an Institute aided by grants from an Agricultural Department, the agreement of the appropriate Department is first to be obtained.

The funds needed for such researches as the Council may themselves direct, and the funds to be expended at the sole discretion of the Council on special grants to individuals, to Institutions or to Organisations other than those financed from the Votes of the Agricultural Departments, will be borne on the Vote for Scientific Investigation, etc. As regards Research Institutes receiving normal annual grants administered by the Agricultural Departments and borne on their Votes, a provision will be included in the Departmental Estimates to cover such special services as the Agricultural Research Council decide to assist or initiate.

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* Report of the Committee on Cattle Diseases, Cmd. 4591.

Furthermore, the duties and responsibilities of the Agricultural Research Council as advisers to the Development Commission are set forth in the Revised Note in more definite terms: the Council are to secure the co-ordination of all agricultural research financed from the Development Fund, and, in connexion with the preparation of annual Estimates, they are to submit to the Development Commissioners a financial statement analysing the whole provision proposed to be charged on the Development Fund for the ensuing year for agricultural research. If necessary, and if circumstances permit, they are to advise the Development Commissioners on the allocation of the provision actually made available by the Treasury. Parliamentary responsibility for agricultural research will remain with the Ministers responsible for agriculture, save as regards expenditure by the Agricultural Research Council borne on the Vote for Scientific Investigation, etc., for which the Lord President will answer. Questions as to the interpretation of this Note will be referred to the Committee of Privy Council for the Organisation and Development of Agricultural Research.

It will be seen that much wider powers than they have hitherto exercised are thus secured explicitly to the Agricultural Research Council, while a clear distinction is drawn between expenditure at Research Institutes chiefly maintained by means of grants borne on the Votes of the Agricultural Departments and expenditure on agricultural research elsewhere. Provision is made whereby differences in interpretation can be settled. The scope of the activities of the Council, and their relationship with the Departments and the Development Commission, are more clearly defined.

The Report of the Agricultural Research Council to the Committee of Privy Council, appended hereto, describes the continuation of the comprehensive survey of the agricultural research now being carried on in Great Britain, especially in those Institutes partly or wholly supported by public funds.

In the course of the survey and outside it, in response to requests for advice on special points from the Agricultural Departments or the Development Commission, a number of Reports have been prepared. Those describing the normal work of the Agricultural Research Council, eighteen in all, were submitted to the Committee of Privy Council, and copies sent for information to the Treasury, the Agricultural Departments and the Development Commission. Those drawn up in connexion with requests for advice were sent direct to the Body concerned, copies being submitted to the Committee of Privy Council.

All Agricultural Research Institutes supported wholly or partly by public funds have now been visited by Committees or Sub-Committees of the Agricultural Research Council. The information so acquired has not yet been fully digested, but the Report of the Agricultural Research Council appended hereto, shows that the Council are, on the whole, favourably impressed with the work going on. There seems to be little evidence of unnecessary duplication, and many individual members of the staffs are carrying on investigations which promise to produce either new fundamental scientific knowledge or useful light on practical problems. Nevertheless, the Council's Report indicates certain places where they consider that the present system shows, or has shown, weakness. On individual points the Council's Report must be consulted, but one or two examples of generalities may here be summarized.

The Agricultural Research Council hold that a close link should exist between research and teaching. They wish to maintain, and where broken to re-establish, the connexion between Research Institutes and neighbouring Universities or Agricultural Colleges. They wish to secure that every advanced teacher who can and will carry on research work should have leisure to do so; and conversely, while recognising that some have no facility for teaching, they consider that most research workers are the better for some teaching duties. Secondly, the Council consider it essential that salaries of Directors and other senior members of the staffs of Research Institutes should be adequate to secure and retain the best men, and, at the other end of the scale they wish to provide easy ways out of the research service for those who show, after adequate test, that they have no power of advancing knowledge. It will be seen that the Agricultural Research Council have done much, and plan to do more, to further these objects.

In the first Report of the Agricultural Research Council (p. 114) an account was given of the Memoranda of the Agricultural Departments on the present position of research in animal diseases and of the developments considered desirable in the near future, and the advice given by the Agricultural Research Council after a study of the problem was described. The question of obtaining a flow of well-trained recruits for the staffs of Research Institutes led to the consideration both of veterinary education generally and of the provision of studentships for promising men.

During the two years under review, progress was made with the rebuilding of the Royal Veterinary College, the Hospital and Canine Block being first completed. On the recommendation of the Agricultural Research Council, the Committee of Privy Council resolved that the rebuilding of the main block of the College ought to continue without interruption, and that the grants from public funds already promised should be made available, as and when required. The Ministry of Agriculture and Fisheries, the Development Commission and the Lords Commissioners of Your Majesty's Treasury having accepted this recommendation, the building is now proceeding, and the long-standing need for a Veterinary College in London worthy of the importance of the subject will soon be met.

In June, 1934, two Studentships in Animal Health were awarded on the Council's advice and in June, 1935, two. The Students have begun courses of study or research approved by the Agricultural Research Council.

While the entry for Agricultural Research Scholarships has been satisfactory, the number and quality of candidates for the Studentships in Animal Health have not been as high as could be wished. On the advice of the Agricultural Research Council the Departments of Agriculture are now considering whether it would be advisable to initiate a second scheme, whereby men who have taken honours in Natural Science should be given Scholarships to enable them to obtain a Veterinary qualification. Again, the University of Cambridge, with the approval of the Royal College of Veterinary Surgeons, has sanctioned in principle and is working out in detail a scheme for a Diploma in Veterinary Science, which it is hoped will meet the needs of the abler men. The Committee agrees with the Council in holding that this scheme is of great importance for the future of the Veterinary profession. The drain on the staffs of Research Institutes concerned with the study of animal diseases, and the difficulty of securing recruits for those staffs, a state of affairs no doubt due in large measure to the recent extension of veterinary services in the counties, has caused the Agricultural Research Council grave concern.

In their first Report, the Agricultural Research Council explained their desire for closer co-operation between the Royal (Dick) Veterinary College, Edinburgh, and the Animal Diseases Research Association at Moredun. The Committee of Privy Council is glad to learn that, during the first year now under review, a Report of the Research Committee of that Association was received, in accordance with which a Research Board for Veterinary Science in Scotland has been set up. This Board, it is hoped, may form a link between the two bodies mentioned above, and between them and the University of Edinburgh, and may in co-operation with the Agricultural Research Council co-ordinate with research done by them any other work on animal diseases going on in Scotland.

As regards special provision in England for research in animal diseases, the scheme for developing the resources of the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at New Haw, Weybridge, approved by the Agricultural Research Council in 1933, has been advanced a stage in 1934 and 1935. At its meeting on the 6th February, 1934, the Committee of Privy Council resolved that the extension of buildings and staff, and especially the purchase of additional land, should be regarded as a matter of urgency and carried through at once. Steps have been taken to give effect to this resolution.

The special Committees originally set up by the Agricultural Research Council to enquire into the present state of knowledge of the more important animal diseases and to recommend what additional researches were required, and subsequently asked by the Council to remain in existence as general co-ordinating bodies, were busily engaged during the years 1933-34-35. Reports or interim reports submitted by the Agricultural Research Council to the Committee of Privy Council comprise those on Contagious Abortion and Undulant Fever, Swine Fever and Similar Diseases, Johne's Disease, Braxy-like Diseases of Sheep, Fowl Paralysis and Coccidiosis.

To give effect to most of these Reports, the Agricultural Research Council, as described in their annexed Report, have made or recommended additional grants to existing Institutions to provide for special researches on different subjects. The action taken has involved considerable expense, as may be seen from the rise in the amount placed at the disposal of the Council for research grants from £6,000 in 1933-34 and 1934-35 to £15,525 in 1935-36. These provisions involved no change in principle, but, as explained above, the recommendations in regard to contagious abortion raised the broad question of the powers of the Agricultural Research Council itself. A majority of the Council's Committee on *Brucella abortus* Infection in Animals and Man reported in favour of concentrating the work on contagious abortion at one farm centre under the control and direction of the Committee, a minority presenting a separate report advocating an expansion of the work at existing Institutes. The Animal Diseases and Animal Nutrition Committees of the Agricultural Research Council approved the Majority Report after prolonged consideration, and the Council themselves adopted it unanimously. After much negotiation, a compromise was adopted in principle by the Council in consultation with the Agricultural Departments, whereby fundamental work involving the use of large animals should be continued for the time being at the Institutes, suitably strengthened, where necessary, for this purpose, while definite problems, involving the use of large animals in considerable numbers, should when the Council decide they are ripe for such treatment, be referred to a farm centre to be established by the Agricultural Research Council under the powers now defined as belonging to the Council by the Second Note on Administrative Arrangements. These arrangements were submitted to the Committee of Privy Council after the close of the period now under review. Towards the end of this period the Agricultural Research Council were informed that the Milk Marketing Board had set aside a sum of £2,000 in each of the years 1934 and 1935 for work on contagious abortion of cattle, and had decided to place the sum of £4,000 thus available at the disposal of the Agricultural Research Council for extending and quickening the work on this disease under the co-ordination of the Council's Committee.

Leaving the subject of Animal Diseases, we may refer briefly to a few among the many other Reports of Committees and Sub-Committees presented to the Agricultural Research Council during the two-year period under review. Among the Standing Committees, the Economics Committee presented a Report summarizing the work of the Oxford Institute and of the Advisory Economists. A Committee was appointed by the Agricultural Research Council in 1933 to confer with the Agricultural Departments regarding the future of the agricultural research work hitherto financed by grants from the Empire Marketing Board, but which on the dissolution of the Board were not thought to be suitable for co-operative assistance from Empire countries. The Reports of this Committee dealt with work thus supported at research stations at East Malling, Long Ashton, Aberystwyth, Rothamsted, Cheshunt, Cambridge; at the Harper Adams College, the Rowett Research Institute, the Station of the Scottish Society for Research in Plant Breeding, and the Institute of Animal Genetics at Edinburgh. They were accepted by the Agricultural Research Council, the Departments of Agriculture and the Development Commission and were instrumental in securing the continuance of the more important research work on the Votes of the Departments or, in a few cases, as a direct charge on the funds of the Council.

Eleven Reports have been received by the Council giving accounts of visits of Sub-Committees to various Research Institutes.

Towards the end of the period under review a Report on the Preservation of Grass and other Fodder Crops was published by the Agricultural Research Council. It is hoped that this will be the first of a series of Reports on special subjects analogous to those published by the Department of Scientific and Industrial Research and the Medical Research Council.

Sir John Farmer was obliged for reasons of health to resign his membership of the Agricultural Research Council from the 30th September, 1935. We desire to record our appreciation of the valuable services he has rendered, and to associate ourselves with the tribute paid to him in the Report of the Agricultural Research Council.

It was with deep regret that we learned of the decision of Sir William Dampier to resign from the office of Secretary to the Agricultural Research Council on the 30th September, 1935. Sir William accepted the invitation to become the Council's first Secretary for a limited period only. He has given to the Council his services in generous measure and we are indebted to him for the wisdom, judgment and foresight which he has brought to bear on the Council's affairs during the first years of its existence. It gave great pleasure to the Committee of Privy Council to appoint Sir William to be a member of the Agricultural Research Council on his retirement from the Secretaryship.

The present Report covers the third and fourth years of the existence of the Agricultural Research Council. It shows a steady growth in the functions and work of the Council, and, as explained above, it ends with a definite acknowledgment, in a new Note on Administrative Arrangements, of a broader interpretation of the powers and duties of the Council. The way is now clear for even greater usefulness in the important field of knowledge covered by the activities of the Agricultural Research Council. The Committee of Privy Council, as in the first Report, desire to express their high sense of the work done by the Agricultural Research Council, and their confidence that the wider powers, now entrusted to the Council, will be well and usefully employed.

J. RAMSAY MacDONALD,
Lord President.

E. J. Butler,
Secretary of the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

24th September, 1936.

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL

For the period October 1933 to September 1935

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH.

I. INTRODUCTION

MAY IT PLEASE YOUR LORDSHIPS,

The Agricultural Research Council beg leave to submit the following second Report upon their proceedings. It covers the third and fourth years of the Council's existence, the period from the 1st October, 1933, to the 30th September, 1935.

The period has been marked by a growth in the activities of the Council, which has led to an increase in the business falling upon the staff.

Sir William Cecil Dampier, Sc.D., F.R.S., was the part-time Secretary of the Council from the start of their work until his resignation in September, 1935. Mr. E. H. E. Havelock, O.B.E., now Secretary to the Development Commission, acted as Assistant Secretary of the Commission and the Council until the 31st December, 1933. He was appointed Administrative Secretary to the Council from the 1st January, 1934, and as from the same date Mr. F. R. W. Jameson, D.S.O., M.C., was appointed Assistant Secretary to the Development Commission, and also Assistant Secretary to the Council. Accommodation has always been provided in the offices of the Development Commission, and assistance has also been rendered by other members of the staff of the Commission. On the resignation of Sir William Dampier, a full-time post of Secretary was created and was filled by the appointment of Mr. E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S. The increase in the work of the Council has made it necessary to provide for additions to the staff of the Development Commission, as, at the request of the Treasury, the Development Commissioners have readily agreed that the administrative and clerical work of the Council should be undertaken by the Commission's staff, which requires to be strengthened for that purpose. The arrangement is one which is beneficial to both organisations and is in the interests of sound administration, since it is from the Development Fund that by far the greater part of the sums made available for agricultural research is found.

On the 24th March, 1934, a Supplemental Charter was granted by His late Majesty, increasing the numbers of the Council. Instead of an initial number of 13 and a permanent number of 12, the Council is now to consist of not more than 15 nor less than 12 members, of whom not less than four nor more than five shall be persons appointed on account of their general experience of and interest in agriculture and the remainder shall be persons appointed, after consultation with the President for the time being of the Royal Society, on account of their qualifications in one or other of the basic sciences underlying agriculture.

Your Lordships, after consultation with the President of the Royal Society, have been pleased to appoint Sir William Cecil Dampier (from the date of his ceasing to be Secretary to the Council) as a Member of the Council, thus raising the numbers to 14.

The Council much regret to report that Sir John Farmer, for reasons of health, found it necessary to resign his seat on the Council as from the 30th September, 1935. The Council desire to place on record their high sense of the services which Sir John Farmer has rendered during the past four years. His knowledge of the botanical side of agriculture, his sound judgment and his ripe experience have been of the greatest use in the work of the Council. The appointment of Dr. Butler as Secretary creates another vacancy on the Council.

By the death of Professor S. H. Gaiger in 1934, the Agricultural Research Council lost the services of a valued member of their Committees on Contagious Abortion, Johne's disease and Braxy-like diseases of sheep.

At the expiration of his period of service, Major-General Sir John Moore retired from the Animal Diseases Committee and from the Joint Committee of the Medical Research Council and the Agricultural Research Council on Tuberculosis. New appointments to Committees include Dr. W. H. Andrews, Sir Robert Robertson and Professor W. W. C. Topley to the Scholarships Committee and Professor S. L. Baker to that on Fowl Paralysis and Coccidiosis. The Council desire to express their deep appreciation of the services which have been at all times so fully and ably rendered by the members of their numerous Committees and Sub-Committees. Their names are given in Appendix II and show how wide has been the assistance given to the cause of Agricultural Research by men of science in all parts of the country.

The time under review has been marked by the completion of the preliminary survey by the Council of the work going on in the various Agricultural Research Institutes supported or subsidized from the Development Fund. Visits have now been paid to all such Institutes, though the final Reports on the results have not yet all been completed.

The Development Commissioners recommended, and the Treasury sanctioned, a grant of £6,000 from the Development Fund for the direct initiation or encouragement of special researches by the Council in each of the financial years 1933-34 and 1934-35. Provision was also made in the Civil Estimates of the English and Scottish Departments of Agriculture for additional grants from the Development Fund to meet the cost of special researches in agricultural science recommended by the Development Commissioners on the advice of the Agricultural Research Council. This provision amounted to £3,200 for the financial year 1933-34 and to £2,462 for the financial year 1934-35.

Apart from the meetings of the Council, their Committees, Sub-Committees, Special Committees and Conferences, held in the normal prosecution of the work of the Agricultural Research Council, a new departure was made in 1935. On the 31st May a Conference on research in relation to the Pig Industry was held in the rooms of the Royal Agricultural Society of England, by courtesy of the Society, under the auspices of the Council, with Sir Merrik Burrell in the Chair. The object was to bring together those engaged in the industry, whether as producers or as controllers of factories, and those men of science who are carrying on pig research in the various Institutes or elsewhere. As will be seen below, it was universally recognised that the Conference was successful in informing each group about the problems of the other, and in establishing contacts which show every prospect of usefulness in the future.

During the Spring and Summer of 1935, the question of the powers of the Council arose on the Reports of the Council's Special Committee on Brucella Abortus infection, and it was necessary to refer the matter to Your Lordships' Committee. After much consideration a new Provisional Note on Administrative Arrangements has been drawn up and agreed upon, which defines the duties and responsibilities of the Council more clearly, and confirms explicitly their power to conduct researches either at centres of their own or elsewhere. This Note is printed in Appendix I.

II.—AGRICULTURAL ECONOMICS

During the first two years of the life of the Agricultural Research Council, as explained in the first Report, the survey of the research going on in agricultural economics was postponed on account of more urgent matters. During the third and fourth years, the period now under review, a preliminary survey has been completed.

The Economics Committee of the Agricultural Research Council have held five meetings at which they have discussed the general position with representatives of the Agricultural Departments, with the Director of the Oxford Agricultural Economics Research Institute, the Heads of the Farm Economics Branch of the Cambridge School of Agriculture, and with the local Advisory Economists. The Committee also visited the Oxford Institute, and Sub-Committees visited other centres. The result of the deliberations was summarized in a Report submitted to and adopted by the Agricultural Research Council on the 15th May, 1935.

Organized and subsidized research in agricultural economics began with the establishment of the Oxford Institute in 1913 with a maintenance grant from the Development Commission of £600, to which the University added £300 and Balliol College £50. In 1919 the maintenance grant from the Development Fund was considerably augmented. At later dates, further increments were made until the grant is now just over £8,000 a year. A capital grant of £3,000 was made from the Development Fund on a £ for £ basis towards the cost of extending the building of the School of Rural Economy, in which the Institute was at first housed. But, as the work of the Institute developed, this accommodation proved to be insufficient and, in 1924, a capital grant of £4,000 from the Development Fund was sanctioned for the erection of separate new buildings and their equipment, and the University provided a site in Parks Road, adjoining the School of Rural Economy. The staff at the time of the Sub-Committee's visit consisted of a Director, two assistants Grade I, one assistant Grade II, one assistant Grade III and four ungraded assistants and student-assistants. The administrative and clerical staff comprised a Secretary and Librarian, a sub-Librarian, a Senior Clerk with three assistants and two Shorthand-Typists.

ADVISORY ECONOMISTS

During the years 1923 to 1926 a number of Advisory Economists were appointed. England and Wales is divided into 11 regions, in each of which there is an Advisory Economist attached to a University or an Agricultural College. The following is a list of the regions and of the institutions which serve them:—

1. *Northern Province.*

(Cumberland, Westmorland, Durham and Northumberland.)

Served by Armstrong College, Newcastle-on-Tyne.

2. *Yorkshire.*

Served by the Department of Agriculture, Leeds University.

3. *Midland Province.*

(Derby, Leicester, Lincoln (Lindsey), Nottingham, Rutland.)

Served by the Midland Agricultural College, Sutton Bonington, Loughborough.

4. *Eastern Province.*

(Bedford, Cambridge, Essex, Hertford, Huntingdon, Isle of Ely, Lincoln (Holland), Lincoln (Kesteven), Norfolk, Soke of Peterborough, Suffolk, East, Suffolk, West.)

Served by the School of Agriculture, Cambridge University.

5. *South East Province.*

(Kent, Surrey, Sussex, East, Sussex, West.)

Served by the South-Eastern Agricultural College, Wye, Kent.

6. *Southern Province.*

(Berkshire, Buckingham, Dorset, Hampshire, Isle of Wight, Middlesex, Northampton, Oxford.)

Served by the Faculty of Agriculture and Horticulture, Reading University.

7. *South West Province.*

(Cornwall, Devon, Isles of Scilly.)

Served by Seale Hayne Agricultural College, Newton Abbot, Devon.

8. *Western Province.*
(Gloucester, Hereford, Somerset, Wiltshire, Worcester.)

Served by the Agricultural Advisory Department, Bristol University.

9. *West Midland Province.*
(Salop, Stafford, Warwick.)

Served by the Harper Adams Agricultural College, Newport, Salop.

10. *North West Province.*
(Cheshire and Lancashire.)

Served by the Agricultural Advisory Department, Manchester University.

11. *Wales and Monmouth.*

Served by the University College of Wales, Aberystwyth.

At first each Adviser was provided only with student assistants and clerical help, but more recently it was decided to add permanent technical assistants and provision was first made for these in the academic year 1930-1.

In Scotland an Advisory Officer in Farm Economics to the Department of Agriculture was appointed in 1926, and, at later dates, an Advisory Economist was attached to each of the three Agricultural Colleges.

From the foregoing it will be seen that research in Agricultural Economics is almost entirely a post-war development in this country. As the scheme has developed, it has been necessary to train those engaged in it, since there was no source from which trained men, qualified at once in economics and agriculture, could be drawn. That difficulty is now being overcome. Not only have the workers had to be trained as the scheme has developed, but they have had to devise their own methods of research and to collect the necessary data upon which to work. The great variety of the types of farming in this country adds to the complexity of the problem. Much of the work must be in the nature of local investigation if the economist is to be able to advise the farmers in his area. It is not easy, therefore, to give a brief summary of the work which is being carried out at the Research Institute and the advisory centres. Certain broad tendencies in methods may be discovered, however. The basis of the earlier work was cost accounting. This method has largely been abandoned, because of the expense of preparing cost accounts, and because, on account of their small numbers and selective character, they do not give a representative sample and thus a basis for advice in general farm management. A few complete farm cost accounts are still being carried on by the economists, and enterprise cost studies form a considerable part of the work. The next development was in analysis of the usual financial accounts kept on farms, and this work is still being carried on at most of the centres. The tendency in recent years has been to use also a survey method, whereby enquiries are made by the investigator into the work of all farms in selected areas. This method seems to be the most satisfactory way of securing a sufficient body of data.

The Oxford Research Institute has been engaged in research into agricultural policy on such questions as land tenure, small holdings, rural industries, etc.; farm management including costing, analysis of financial accounts, and general and particular surveys; studies of new systems in farm management; marketing of livestock and milk, and price studies. The Institute also provides training for post graduate students, and for Research Scholars in agricultural economics.

The Advisory Economists naturally tend to concentrate on the problems which are of most interest in their areas, but most of them from time to time engage in research work of a more general character, and many of them have published work which is of more than local interest.

Examples of work which has been undertaken at some of the advisory centres are:—

Cambridge.—From 1923 until 1930 cost accounting studies; since then an economic survey of the Eastern counties, and, simultaneously, cost studies of sugar beet, wheat, strawberries and milk.

Wye.—An investigation into farming costs of production and financial results, a food recording scheme for dairy cows, and a study of the economics of strawberry growing.

Leeds.—Studies of land improvement, economic history, co-operation and marketing and financial results from particular farms over a series of years on the basis of cost accounts from 90 farms.

Seale Hayne.—The study of financial accounts, treating the farm as a unit; labour studies.

The Midland College.—Commodity and farm management surveys.

Harper Adams.—Milk and sugar beet surveys and a poultry investigation in co-operation with *Newcastle.*

Reading.—An agricultural survey of the whole area, followed by the collection of financial accounts on a sample of the farms; the preparation of an index of farming information.

Bristol.—Investigating the accounts of the Wiltshire Agricultural Accounting Society and making enterprise studies on strawberries, sugar beet, poultry and dairy herd management.

Aberystwyth.—Studies of farm management and the marketing of livestock, and livestock produce, standard costs, price studies, investigations in rural sociology.

Many of the centres have co-operated in national investigations into the cost of milk and sugar beet production.

When the scheme for Advisory Economists in England and Wales was set up, an attempt was made to secure a measure of co-ordination in the work throughout the country. The method adopted was for the Ministry to set up a Committee composed of the Director of the Oxford Institute and the Advisory Economists under the chairmanship of an officer of the Ministry or the Director of the Institute. To begin with that Committee endeavoured to secure uniformity of methods in the collection of data by means of costing and financial accounts, which could then be collated by the Oxford Institute. The effort was not a success, because agreement could not be secured as to uniformity of methods, or as to the value of the schemes proposed. Efforts to secure co-ordinated work on other special schemes, such as the costs of sugar beet production, were more successful, while joint schemes such as those for poultry and strawberry production, in which some of the Advisory Economists have co-operated, have been carried through. On the whole, however, the attempt to secure co-ordinated investigation did not succeed and for a time the Committee ceased to function. Recently, however, conferences have been held under the chairmanship of Mr. R. R. Enfield, Head of the new Economics Intelligence Branch of the Ministry. A co-ordinated scheme of investigation into costs of production of milk, financed by the Milk Marketing Board, has also been initiated.

The Economics Committee hold that the Oxford Institute should develop further research into the fundamental problems of economics as applied to agriculture, and should be regarded as the main centre for research of this character. The far-reaching changes, both in methods of production and in distribution, which the agriculture of this country is undergoing, demand careful examination and analysis by an independent institution. Moreover, there is still work to be done in formulating methods of research and in the improvement of technique. When co-operative schemes are set on foot, the Oxford Institute is the appropriate centre for preparing the material for publication. As experience of co-operative effort grows, it ought to be able to give a lead to the Advisory Economists, without any loss of their independence.

The Economics Committee are of opinion that the wisest course in the meantime is to encourage the efforts which are being made to secure a greater measure of co-operation, rather than to embark on any more formal scheme of co-ordination. They are the more convinced of this course because a new factor has emerged while they have been considering the matter. The Ministry has recently set up an Economics Intelligence Branch to study legislative proposals and to provide the Minister of Agriculture with information. While the Committee were assured that this Branch will in no way attempt to interfere with or direct the work of the Advisory Economists, there will necessarily be intimate relations between the Branch and the agricultural economists on the basis of mutual interests, and some time must be allowed before its relations with the economics service can be worked out in practice. It is hoped that the new Branch will further the spirit of co-operation in the service.

The position in Scotland is somewhat different. There the Advisory Officer in Farm Economics to the Department of Agriculture and the Advisory Economists attached to the Agricultural Colleges have been co-operating in a scheme of analysis of financial accounts, from which a series of reports on *The Profitableness of Farming in Scotland* have been issued. In addition, the Advisory Economists have been carrying on investigations into the problems most applicable to their respective areas. The Department of Agriculture has also issued a series of reports on the marketing of potatoes, livestock and cereals prepared by the Farm Economics Branch.

For future developments in Scotland, where the Advisory Service is younger than in England and Wales, the Committee recommended that the policy for the present should be to strengthen the work at the Colleges rather than at the centre, and that additional funds should be made available for this purpose. The work at the Colleges is very satisfactory within the financial limits imposed. With further resources important developments would be possible, especially in the West, where the assistance given to the Advisory Economist is quite inadequate to the work which should be done.

Representations were made to the Economics Committee as to the difficulty some of the Advisory Economists had in securing publication of their work. The Committee recommended that the practicability of the publication of a Journal, under a joint editorial committee of the Oxford Institute and the Advisory Economists, should be considered. A publication of this kind would secure a wider circulation than the Advisory Economists can hope to secure, and ought to be more economical than separate publications, while it would help to bring the Institute and the Economists closer together.

Finally, the Economics Committee stressed the necessity for maintaining the independence of the agricultural economics research service. Far-reaching changes in the economic structure of agriculture in this country are being introduced which will give a very wide scope for economic investigation, and, in the national interest, will need most careful watching by independent observers. The Marketing Boards are finding that they require the help of agricultural economists. The Committee recommended that they should be encouraged to use fully the established agricultural economics service. The Economics Committee strongly urged that where any Marketing Board or other sectional interest desires to secure the services of the Agricultural Economists certain conditions should be observed. Any suggested schemes of research should only be arranged after consultation with the Agricultural Research Council; the Economists must be free to pursue their investigations as independent scientific researches; and the results should be published under the authority of the Economists themselves. Normally the appropriate centre for collating the results and preparing them for publication should be the Oxford Institute.

AGRICULTURAL LEGISLATION

The great change in British economic policy which followed the financial crisis of 1931 was extended to agriculture by fundamental legislation in 1931, 1932 and 1933, and by minor and amending Acts in 1934 and 1935. Summaries of these Acts will be found in "The Agricultural Register" for 1933-4 and for 1934-5, issued by the Agricultural Economics Research Institute, Oxford. As regards agriculture, the legislation consists of three parts: (i) the organisation of internal production by schemes under the Marketing Acts of 1931 and 1933; (ii) subsidies to the producers of certain commodities; and (iii) the control of imports by tariffs or quotas. Legislation of this kind and the control of produce by marketing schemes involve economic repercussions, both on agriculture itself and on other industries. In framing legislation and in the initiation and guidance of Marketing Boards a knowledge of economics, as well as of politics, is necessary, and a complete study of the problem in all its aspects is desirable. In April, 1934, the Ministry of Agriculture and Fisheries, as has been stated, established a new Economics Intelligence Branch, under the direction of Mr. R. R. Enfield, to advise the Minister on the economic effects of proposed legislative and administrative action.

AGRICULTURAL SURVEYS

In 1931 proposals were on foot for agricultural surveys to be made from Oxford, Cambridge and Aberystwyth, but the need for economy led to the postponement of the schemes for Oxford and Aberystwyth. The work at Cambridge was carried through during the three years 1931 to 1933, by the Farm Economics Branch of the Cambridge School of Agriculture and has proved very useful. In this survey a number of typical parishes were chosen and in each parish all farms were visited. In this way about 1,000 farms in the Eastern Province were examined year by year, and information obtained on output, profits, and other data of interest to agricultural economists.

The Agricultural Research Council have long held that an extension of this survey to the rest of the country, with appropriate modifications to suit local conditions, would help forward fundamental economic knowledge, and they welcome the additional reason for an extension obtained from the side of practical politics. The information should enable those interested to follow the variations in the state of English farming in a way hitherto impossible. The facts will be collected by the Agricultural Economic Advisers, and, since the end of the period now under report, a Committee has been established by the Ministry of Agriculture and Fisheries, containing representatives of the Ministry, the Agricultural Economics Institute, the Advisers and the Agricultural Research Council, to consider what form the enquiry should take, and what modifications are necessary from Province to Province. It is hoped that information which can be collated and generalized for publication will be dealt with and issued by the Oxford Agricultural Economics Research Institute. It is essential that data published and conclusions drawn therefrom should come from sources independent of party politics.

III.—SOIL

In the First Report of the Agricultural Research Council a summary was given of the recent history and present state of knowledge of soil science, and consequently it only remains to give here a short account of the work of the last two years, and the inquiries made by the Committees and Sub-Committees of the Agricultural Research Council.

The chief centres of soil research in Great Britain are Rothamsted, the Macaulay Soil Research Institute at Craigiebuckler, Aberdeen, and University College, Bangor, North Wales. The problems of soil are very different in the south-east of England, as investigated at Rothamsted, and in Scotland and Wales; hence the need of three research centres.

Rothamsted Experimental Station.

Several Sub-Committees of the Agricultural Research Council have visited Rothamsted during 1934 and 1935 and a full report upon the Station has now been prepared. As regards soil physics, they found that the dynamometer estimations of soil resistance have been largely replaced by other measurements. A comparison of the effects of the plough, the roto-tiller and the gyro-tiller is being made on four rotations of three crops: ninety-six experimental plots are in use and the investigation will last for twelve years. Preliminary results indicate that rotary cultivation encourages those weeds that grow from fragments; it gives a looser tilth, the germination of a field crop is earlier, but the final yield seems to be about the same as with the usual cultivation, though it may be found to be obtained with less cost. The stirring action of the gyro-tiller seems to leave a better tilth than does the roto-tiller. Neither potatoes, sugar beet nor kale responded to cultivation more intensive than that necessary to keep down weeds.

Investigation of rapid "single value measurements" has been continued. They have been applied by Mr. J. R. Coutts and others to a large range of soils, and examined statistically by Mr. E. W. Russell.

In regard to the water relations of soils, the practice had been in the past to determine the percentage of water in the soil without relation to the growing plant. Rothamsted has approached the problem from the point of view of the balance between the soil on the one hand and the plant root on the other. Dr. R. K. Schofield has devised a scale for measuring the intensity by which water is held by the soil and its power of delivery to the plant. This is, in effect, a water supply scale parallel with the pH scale for acidity or alkalinity. Two values are necessary at each point, for the water relations of a soil differ according as the soil is being dried or is becoming wetter.

Fundamental work had been largely devoted to the factors concerned in determining crumb structure, which is the essential point in soil tilth. Stability in crumb is greater for calcium clays, and is increased by some kinds of micro-organic action. The absorption of water, as indicated by the electric conductivity and dielectric constant, appears to occur discontinuously in steps. As a check on the work on clay, and as an investigation into the structure of plastic substances in general, experiments have been made on dough, the physical properties of which are of practical importance to bakers.

The physical qualities of clay are found to be connected with its chemical power of base-exchange, the buffer capacity with the heat evolved on wetting, and the flocculation of clay suspensions with the acidity or alkalinity as expressed as pH. The most important single factor in clay is the water content of the colloid and the chemical state of the water as " bound " or " free ". For further physical investigation ultra-microscopic, X-ray and supersonic examination seem necessary. For research on these deeper problems to be effective the Agricultural Research Council consider that an increase of staff, including a mathematical specialist in the theory of plastic materials, would be necessary. But plenty of useful work of more proximate importance is ready to be undertaken.

Much of the physical investigation leads naturally to chemical problems. The Chemistry Department at Rothamsted, in spite of cramped quarters, works with clear aims at theoretical and practical aspects of the main problem of developing methods for obtaining more precise agricultural information on chemical questions. On the fundamental side, the general point of the work is the analysis of the chemical problems of soil formation and soil fertility, such as the composition of clay (that is of the clay fraction obtained in mechanical separation) and the movement of bases in the soil profile. In American soils, the published data on which have been statistically examined at Rothamsted, the composition of the clay fraction varies not only with geological formation, but also with rainfall and temperature. Continuing this investigation, a study has been made of the influence in Burmese soils of rainfall on the silica-alumina ratio of clays: the ratio falls much faster with increasing rainfall in red soils than in black. The equilibria between clays and salt solutions are being traced in the relatively simple system of bentonite in mixtures of sodium and calcium acetates. The fixation of phosphates in certain soils is being studied in the laboratory and field. The efficiency of superphosphate as a fertilizer is found to depend on the composition of the clay. Work on organic soil constituents in their relation to the changes in inorganic nitrogen is also in progress.

On the practical side much attention is devoted to improving methods of field experiment. Here the statistical department is concerned, and advances have been made in statistical theory, as well as in its practical application to field experiment, where modern statistical methods allow the effects of several variables to be estimated in the same investigation. The effect on soil of long continued field trials is being investigated. For instance, the continuous growth of wheat and barley with no farmyard manure results in a loss of one-third of the organic matter of the soil in fifty years.

The effect on yields of subsoil conditions is great and analyses are now not confined to the top soil. In heavy soil, the structural units of the clay allow nitrates washed from the soil in autumn to be stored in the subsoil, so that they are available to the deep rooted wheat crop in the following season; consequently in heavy soil the wheat yield is largely determined by the nitrate contents of the soil during the previous summer and autumn. As regards phosphates, hitherto basic slags have been of either high or low citric acid solubility, but now intermediate qualities are coming on the market and these are receiving careful investigation.

Work on the effect of fertilizers on the quality of crops has hitherto shown little evidence that any significant improvement in quality can be effected by any system of manuring. This work involves analyses of crop samples from many of the field experiments for elucidation of the factors involved.

The work which has a bearing on soil problems of the botanical, bacteriological and microbiological departments at Rothamsted involves water and pot culture experiments to study the effect of potash, and of traces of the minor elements, such as boron and molybdenum, on plant growth; investigations of the variation in the number of bacteria in the soil and its effects, of the mode of action of root-nodule bacteria, the mechanism of root hair infection by them, and their adaptation to different varieties or species of plants; work on the interaction of various soil-inhabiting micro-organisms, on the nitrite-forming bacteria, on the respiratory changes of soil bacteria and on the chemical changes caused thereby in various substrata. The last-mentioned has arisen from investigations on the purification of the no longer necessarily troublesome effluents from sugar-beet and milk-products factories.

The Macaulay Institute, Aberdeen.

The Macaulay Soil Research Institute was inspected for the first time by a Sub-Committee of the Agricultural Research Council on the 23rd May, 1934, and their Report was adopted by the Council on the 14th November. The Institute was founded in 1930 with the aid of a benefaction of £27,000 from Mr. T. B. Macaulay. The cost of the house and grounds at Aberdeen was chiefly met from this benefaction, which also included funds for a demonstration farm in the Island of Lewis.

The work at the Institute is primarily chemical, but it is closely linked with geology and with practical farming. Broadly speaking, its purpose may be said to be to study the soil as a natural object on the one hand, and as the raw material employed by the farmer on the other. Thus, investigation begins at a point at which the direct interest of the geologist ends, and it ends where farmers' questions on fertility, or lack of it, can be answered adequately. It may be observed that the group of studies now centred at the Macaulay Institute are entirely appropriate to a Scottish institution, linking as they do the branch of science which in the past century owed so much to Scottish workers with the industry in which Scotland then excelled. The soils of north-eastern Scotland are in a sense younger than in the south-east of England and their mineral composition closer to the original rock minerals. Their response to specific fertilizers is thus more definite.

Dr. W. G. Ogg, the Director of the Institute, is interested in soil classification, and in the practical problems of the reclamation of poor and peaty soils, especially on the farm in the Island of Lewis.

Dr. R. Hart's main interest is the mineralogical analysis of soils and subsoils, including boulder clays. This work gives a clue to the state of the soil reserves and helps in soil classification. In connexion with the recent geological survey of East Kincardineshire, a soil map is being prepared based on an examination of soil profiles. Otherwise soil boundaries are not being mapped as they are in England, e.g., in the West Midlands. Mr. M. M. Monie has given attention during his part-time services to the Institute to drainage, soil texture surveys and soil colours; Mr. A. Muir, who has first-hand knowledge of Russian methods of soil survey, is studying the origin of soils, especially the virgin soils in some afforested areas, and the changes produced by cultivation.

Dr. A. B. Stewart and Dr. I. M. Robertson, both partly engaged on advisory work, are studying, by pot culture methods, the response to artificial manures of soils which have been analysed chemically and mechanically. In the expansion of this side of their activities the Agricultural Research Council was able to help by a grant of £100 in 1934. At the pot culture station a series of soils typical of many of those common in Scotland is provided, chemical and mechanical analyses of each type have been made, and their response to artificial manures is noted each season. When soils are sent in by farmers they are examined in the laboratory and their character, together with the information provided in a schedule which applicants for advice are required to fill in, enables the Institute to provide a reasonably reliable opinion on the response which will be made to treatment with lime or artificial manures. As experience of the season's effects accumulates, and knowledge of local soils extends, the reliability of the advice increases. The Sub-Committee considered that the research and advisory functions of these men act and react favourably on each other. They are better able to advise because they research, and they obtain useful information from many of those who ask for advice.

In 1919 three lysimeters were set up on the Craibstone Farm, attached to the North of Scotland College of Agriculture. Mr. H. D. Welsh has analysed the drainage waters from crops grown in a five year rotation, and treated with different manures. The main purpose is to provide a balance sheet of the soil's gains and losses under different methods of treatment. Among his results, mention may be made of those produced by the intensive manuring of grass. A large dressing of sulphate of ammonia (4 cwt. per acre) produced in a dry season a relatively small increase in yield, but nitrogen was almost absent from the drainage waters, being retained by the soil. In the soil and climate of Aberdeen little loss of nitrogen occurs in a cropped soil, but the losses of lime are large, and the lime status of the soils is important.

Three research students were working at the Institute. Mr. Burns is interested in the soil requirements of trees; Mr. Whelan is tracing the effects of lime on soil texture and on crop yield as it passes from soil to subsoil; Mr. Williams is examining the relations between soil drift and the underlying rock foundations.

The Sub-Committee reported that the work of the Institute was good, but that it was hampered by want of funds. Owing to the financial crisis, Mr. Macaulay had been unable to help as much as he had intended; a debt had accumulated, and both capital requirements and maintenance needs were above present resources.

As a result of recommendations made by a Sub-Committee appointed to examine the present position of spectrographic research on soils, the Agricultural Research Council made a grant to the Macaulay Institute in 1935 of £850 for the purchase of a photometer flame spectrograph, and accessories, and the salary for one year of Dr. R. L. Mitchell, who was selected to study methods of spectrographic analysis of soils. Subsequently, Dr. Mitchell spent some time in Sweden with Professor Lundegärdh, the chief exponent of these methods.

The Lundegärdh spectrographic analysis method involves the photographing of the spectrum emitted when a spray of solution containing certain cations is injected into an air-acetylene flame. The intensity of the spectrum lines so obtained is measured photo-electrically and the quantitative amount of the element determined by reference to the spectra of standard solutions. The method is rapid, so that a large number of determinations of a particular element can be made in a short time. It is particularly useful for the estimation of calcium, magnesium, sodium and potassium in the soil and the relationships of calcium to strontium and sodium to potassium in soil profiles. Manganese can also be easily and accurately determined in small quantities.

Work on clay particles at the School of Rural Economy, Oxford.

A grant of £300 was made in 1935 from the Council's funds to the School of Rural Economy at Oxford for an investigation by Mr. J. Russell of the changes which take place in clay particles during dehydration. The methods employed were worked out by Mr. Russell while holding an Agricultural Research Scholarship in Professor E. K. Rideal's Laboratory in Cambridge, and the work is being carried out in Mr. C. G. T. Morison's Soil Science Laboratory at the School of Rural Economy. It is a natural extension of work already in progress at Oxford and has distinct bearings on problems arising in connection with the drainage of land and on some of the Rothamsted investigations.

SOIL SURVEYS.

As was previously explained in the Council's first Report, systematic surveys of the soils of certain areas in Great Britain are being carried out on a co-operative basis by a number of soil investigators who meet usually twice a year to compare notes, plan methods of surveying and discuss difficulties of classification which may be met with in the course of field work.

This group forms the Soil Surveyors' Conference. In England and Wales members represent chiefly the Advisory staffs centred at Agricultural Colleges and University Departments of Agriculture, in Scotland the Macaulay Soil Research Institute and the Agricultural Colleges. The Geological survey is always represented at meetings, and one Officer of the Survey is a member of the Executive Committee. This Committee, of which Professor G. W. Robinson of Bangor is Chairman, arranges the business for each Conference, and also correlates the work of local surveyors with the object of securing uniformity in methods and in nomenclature in different districts.

The Executive Committee further arranges for an annual field meeting at a centre, selected after consultation with geologists and agriculturists, which provides a considerable variety of soils for study and is likely to raise unsettled questions in soil classification. This meeting, which last year was held in South Devon, with Dartington Hall as a centre, lasts a week. Members present divide up into groups; each group, which as a rule includes one of the most experienced surveyors, goes over the whole area selected for examination and prepares a soil map. The maps and conclusions reached are subsequently discussed.

Pedology is a young and vigorous branch of science, and that there is both room and need for discussion the following incident will illustrate. It does not refer to a meeting of our own soil surveyors but to a field meeting held during the Oxford Congress referred to below. Of this excursion several of the chief authorities on soil classification were members. A sentence from a personal letter describing the excursion is illuminating: "We saw soils developed on the Oolite and Greensand Formations as well as those found on the Malmstone and Chalk. I think everybody was rather relieved when we arrived at the Chalk and could all pronounce it to be a Rendzina without fear of much argument. Professor ——— (an American delegate) made a very wise remark when he said that it is not certain that all the great soil groups of the world have been discovered, and it certainly seems sometimes as if we tend to force soils into a group in spite of the fact that they don't quite fit."

It should be explained that at the Congress there had been much discussion on soil classification. A map of Europe had been presented in which its soils, including those of Great Britain, had been classified into generally accepted world groups. But these world groups are based on studies which have made furthest progress in Continental areas, especially in the U.S.A. and Russia; the representatives of this country who were associated with the preparation of the map had left puzzling questions unsolved. As the above quotation shows, experts from other countries found that the insular climate and varied geological structure of England, coupled with features depending on the long interference of man with nature, had resulted in soils which they, too, found difficulty in assigning to a certain place in the scheme of international classification.

Reading Area.—A report on an intensive survey of the Eastern part of the Vale of the White Horse, which has been carried on for some years by Dr. F. F. Kay of Reading, has now been published.* This work, begun in 1929 to provide information required in connection with fruit crops, developed into a full study of four natural areas which, within the limits of a district 15 miles long and 10 miles wide, include a wide range of soils.

The natural areas are formed by (1) Downs on the Middle and Lower Chalk formations with associated drifts, (2) a terrace on the Upper Greensand, (3) the Vale, on Gault and Kimeridge clays and (4) rising ground on the north of the Vale overlying Corallian rocks. In this small district no fewer than twenty well defined soil series were distinguished, excluding alluvium and other recent immature soils. These series were mapped and are described in full in the report. Chemical and mechanical analyses are given not only of the different soil series but of their horizons, together with notes on the natural vegetation and crops.

Dr. Kay's report is of exceptional interest because of the discussion of methods adopted in surveying and of the complete presentation of data; also because it illustrates how much useful work awaits those who adopt modern methods in approaching the study of soils. The study of local soils was begun by the University College (now University) of Reading over thirty years ago, and in the interval several publications recording observations on the composition or the geological affinities of soils have appeared. A comparison of these earlier studies with Dr. Kay's report illustrates the progress that has recently been made by soil surveyors.

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* Reading: Bradley & Son, Ltd., 1934 (Bulletin XLVIII of the Faculty of Agriculture and Horticulture, University of Reading).

Bangor Area.—At Bangor a systematic soil survey of Wales is being continued under the direction of Professor G. W. Robinson. During the year a study of the characteristics of mountain soils has been begun. The crystalline rocks which formed the parent material in the area surveyed were found to exercise little influence on mountain soils, which were mainly the result of topography and climate. Where drainage is free iron podsols develop, and with impeded drainage peat forms. Where the topography allows, peat to a depth of six feet or more accumulates, but the usual profile found consists of two to three feet of peat over a few inches of bleached silty loam, passing down into brown gravelly loam. In all cases there was a great lack of lime. One of the Bangor soil surveyors was seconded to Armstrong College to initiate a soil survey in the North of England.

Harper Adams Area.—The area surveyed and mapped in the West Midlands by Mr. Morley Davies and assistants is now extensive, and as an illustration of the methods adopted by British soil surveyors, as well as for the interest of the soils themselves, an area in North Shropshire was selected for detailed examination by overseas members attending the Oxford Congress. A descriptive account of the methods followed and of the soils mapped was published* in the Empire Journal of Experimental Agriculture, and was used by the Excursion Committee of the Congress as a Guide for visitors.

Bristol Area.—Dr. T. Wallace and Dr. D. A. Osmond, who are specially interested in soils used for fruit growing, have continued systematic surveying and mapping in the Bristol area. Specimens of typical soils from this area together with illustrations of the influence of soil on tree growth formed an interesting feature of the exhibit at Oxford prepared in connection with the Soil Congress.

Kent Fruit Growing Area.—An intensive survey of the fruit growing soils of the Lower Greensand in Kent was carried out by East Malling Research Station and the South-Eastern Agricultural College at Wye some years ago; but, chiefly because of changes in the staff engaged and the large amount of detailed information to be worked up, the results have only recently been published.* The survey included a detailed examination of about 4,000 acres of land by soil experts and of over 900 fruit plantations by skilled horticulturists. The results bring out very clearly the value of an intensive study of soils to fruit growers. The work was limited in scope, it concerned itself with the Lower Greensand of Kent only, and the purpose was to provide a sound basis for advisory work among local growers. The survey is also incomplete; while the soils were examined fully and classified into no fewer than twenty-six series, most of them represented by several texture types (as in American surveys), the boundaries of the soils were not mapped in the field. Mapping had to be omitted for lack of time. Thus while the survey provides much interesting information, is of immediate value for local advisory work and is well fitted to prove to fruit growers the benefits they are likely to derive from careful soil studies, the ground will have to be gone over again before such maps as are being constructed in other areas can be prepared.

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* Empire Journal of Experimental Agriculture, Vol. II, Nos. 6 and 8.

Other Areas.—As mentioned above, a survey has been begun in Northumberland. An experienced surveyor from Bangor has been lent to Armstrong College, Newcastle, to initiate work there. In Scotland the Macaulay Institute has a survey of Kincardineshire soils in progress, and work in Ayrshire is being carried on by the Glasgow and West of Scotland Agricultural College.

CONGRESS OF THE INTERNATIONAL SOCIETY OF SOIL SCIENCE.

For those engaged in soil research the chief event of the year was the meeting of the third Congress of the International Society of Soil Science at Oxford. The two earlier meetings had been held in the United States in 1927 and in Russia in 1930. The Oxford meeting was attended by nearly four hundred members, of whom about sixty were official delegates from over thirty countries. The Congress assembled on the 30th July at Rhodes House, Oxford, where, after members had been welcomed by the Vice-Chancellor, Sir John Russell delivered his Presidential address. Subsequently the Congress met for six plenary sessions between the 31st July and the 7th August. At these sessions 18 papers, or reports, were discussed. To the Sectional meetings

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* M.A.F. Bulletin No. 80. *Fruit Growing Areas on the Lower Greensand in Kent.*

92 papers were contributed. After the Congress about half the members made a tour of Great Britain for the purpose of studying its soils. The papers read have been published in two volumes of Transactions;* their number and range show the very rapid growth in interest in Soil Science which has developed since the International Society came into being in 1924.

Apart from the large attendance, the quality of the papers and the interest shown in subsequent discussions at meetings, a feature of the Congress was the fine exhibit of soil profiles and other specimens arranged by Mr. C. G. T. Morison and Mr. G. R. Clarke of the Oxford Soil Laboratory. British soils were fully represented, and specimens had been obtained from many countries. There was, for example, a notable exhibit from China, where systematic soil surveys are being actively prosecuted by the Chinese Government.

The arduous work of organising a very successful meeting was undertaken by a Committee, of which Dr. E. M. Crowther was Chairman and Mr. G. V. Jacks was Secretary. A large amount of preparatory work was called for both in arranging exhibits at Oxford and in preparing sections showing typical soils *in situ* for the excursion. Towards the cost of these exhibits small grants, amounting in all to £200, were made by the Agricultural Research Council.

It was with great regret that the Council learned of the death, shortly after the Congress, of the senior delegate of the United States Government, Dr. Curtis F. Marbut, who died in Manchuria on the 25th August while on his return journey. Dr. Marbut, who was chief of the United States Soil Survey, had taken a leading part in founding the International Society of Soil Science and was President of the Commission dealing with Surveys and Mapping at the Oxford meeting. For 25 years he had directed the great American Soil Survey, which has now mapped and described over 1,000,000,000 acres in the United States. Although in administrative charge of a large department he was an indefatigable field worker, who had examined the soils of most European countries, had made preliminary studies of soils in Africa and South America, and was on his way to advise the Chinese Government on the work in progress in that country when his death occurred.

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* London, Thomas Murby & Co. 1935.

IV. PLANTS

PLANT PHYSIOLOGY.

Electro-culture of plants: Imperial College of Science and Technology.

The work on the so-called electro-culture of plants, which has been carried on for many years under the auspices of the Ministry of Agriculture and Fisheries and chiefly at or under the direction of the Imperial College of Science and Technology, was examined by a Sub-Committee of the Agricultural Research Council in May, 1935.

Between 1918 and 1922, besides laboratory and pot experiments, field work was done. At an early stage it seemed that an overhead, high tension electric discharge produced a considerable increase in the yield of spring sown cereals. But, as it was impossible to obtain uniform results, or even to repeat the increase with certainty, it was decided in 1922 to discontinue the field experiments and, following up interesting results derived from pot-culture experiments at Rothamsted, to concentrate on small scale work designed to acquire further knowledge of the physiological effects of variations in the period and intensity of the discharge, the effect of the discharge in combination with different types of manuring, and other factors.

It has been found that in general a larger reproductive growth, as compared with vegetative growth, is obtained by electrification, and that this change is due to a reduction in the percentage of sterile flowers in the ears. Moderate nitrogenous manuring tends to increase this effect. There is a slight reduction in the amount of tillering, with an increase in the rate of growth of the individual tiller. The treatment used (10,000 to 15,000 volts, giving about $2 \cdot 5 \times 10^{-10}$ ampère per plant) has most effect when applied for a period of six to nine weeks in the middle of the growing season.

These general results, however, are not uniformly attainable. For instance, in 1932 there was a negative result. In 1933 the negative discharge reduced the size of the ears and increased the flower sterility significantly as compared with the opposite effects of the positive discharge.

Professor V. H. Blackman described to the Sub-Committee the work done during 1934, when again inconclusive results were obtained, and the plan of work for 1935.

After a full discussion with Professor Blackman and Dr. F. G. Gregory, the Sub-Committee came to the unanimous conclusion that the number and complex interaction of the different variables made it unlikely that any results would be obtained of sufficient direct or immediate value either for the fundamental problems of plant physiology or for practical agriculture and horticulture. The Sub-Committee therefore recommended that the experiments should be discontinued at the end of the present season. If this were done, Professor Blackman considered that he could dispense with the services of a whole-time assistant, now on a temporary engagement, and of another assistant, at present employed on the experiments during the summer. The total saving he reckoned at about £300 a year.

PLANT BREEDING.

Plant Breeding Institute, Cambridge.

The work of the Plant Breeding Institute, Cambridge, was described in the last Report. In October, 1934, the Agricultural Research Council decided to make a grant of £250 to the Institute towards the cost of an exploratory investigation of the possibilities of producing improved forage crops by synthesising new polyploid species of Brassica. The work involved the crossing of as many species of cultivated Brassicae as possible, and producing polyploids from the hybrids by callus formation or in some other way. The new species would be crossed among themselves with a view to getting segregates of economic value. By this means it might be possible to develop from crosses between kales, cabbages, turnips, etc., new plants of enhanced vigour that would be valuable as fodder crops. Mr. H. W. Howard was appointed to assist in this work for one year from July, 1935.

Welsh Plant Breeding Station, Aberystwyth.

A Sub-Committee of the Agricultural Research Council visited the Welsh Plant Breeding Station, Aberystwyth, on the 8th to 10th November, 1933, and met in London on the 11th January and 14th March, 1934, when they discussed again the whole position with Professor R. G. Stapledon.

The Station had been carrying on certain work financed by the Empire Marketing Board. The suppression of that Board created difficulties at many places, and not least at Aberystwyth. The Sub-Committee had to advise the Agricultural Research Council and through them the Ministry of Agriculture and

Fisheries, the Development Commissioners and the Treasury, on what work could be dropped, and what had to be supported through other sources. While they thought that some of the Empire Marketing Board work should be continued, they looked to effecting economies in other directions.

The Station possesses a range of laboratories, a garden with glasshouses and a bird-proof enclosure, and a farm of 120 acres about 1½ miles from Aberystwyth, lying for the most part on steep hill sides. The Station also makes use of a neighbouring farm belonging to the College, and of experimental plots on pastures on other farms in different parts of Wales, extending to 848 acres on 231 farms in the five-year period 1929-33. There is also a demonstration area some miles from Aberystwyth.

Most of the scientific workers at the Station have been trained at the College, and are familiar with Welsh agricultural conditions.

Although designated a Plant Breeding Station, the work includes the whole subject of the improvement of pastures, and some investigations on arable crops. The chief lines of work may be grouped under the following heads:—

(1) Determination of the characters—botanical, chemical, cultural—which give value to pasture plants.

(2) Improving, by selection or breeding or both, a group of important plants.

(3) The growing on and bulking of seed of improved strains. Technical questions in connection with seed growing are being explored. Measures for getting pure seed sown in quantity are engaging attention.

(4) The cultural methods required to secure the establishment of seed mixtures grown under unfavourable conditions on hill farms. This problem is being attacked on a number of Welsh farms.

(5) The gains in weight of live stock on natural, commercial and new strains of pasture plants; and the effects produced by stock on the pastures grazed by them.

To deal with these subjects the staff is arranged in groups. The raising of new varieties is in charge of Dr. T. J. Jenkin (grasses), Captain R. D. Williams (clovers) and Mr. E. T. Jones (oats). The growing on of seed for the purpose of making field tests, or in the case of proved strains (of which there are now about a dozen) for distribution, is in charge of Mr. G. Evans. Grassland improvement is supervised by Mr. W. Davies (an officer who has recently been lent to

Dominion countries), and extension work is in charge of Mr. M. T. Thomas. The Director, who has made a study of the requirements of pasture plants in Wales, and in many parts of England, has himself given special attention to the selection and breeding of cocksfoot, after ryegrass the most important of the grasses of this country.

The Sub-Committee reported that the general programme was marked by originality, enthusiasm and an energy which strains the Station's financial resources, and, in the growing season, the strength of the staff.

Breeding is in progress on oats, clovers and grasses, and a large amount of new material is being produced. The Sub-Committee held that there should now be concentration of effort on a few strains, which could be grown on and marketed. The volume of work may be illustrated by the case of clover, where 250,000 crosses may be made in a year, though Captain Williams says he has so far raised only one strain which is good enough to distribute to farmers, a white clover which promises to be better than the Dutch and New Zealand types now cultivated. In any case, however, new strains should not be issued too frequently.

The ryegrass seed of commerce is almost exclusively the product of those types which run up quickly to seed in the mixture that constitutes natural ryegrass. Thus an automatic selection has been proceeding of seed bearing strains instead of the leafy types which give ryegrass its value in pastures. Hence improved strains would be of great value, provided the seed could be sold at a price not exceeding 1s. 6d. to 2s. 0d. a pound. There is little doubt that it is only a question of time until the methods now being followed by Dr. Jenkin at Aberystwyth result in improved strains. In the case of ryegrass, there can be no one best strain; there is need for several strains—some for "seeds" hay and two years leys, some for three to seven years leys, some for permanent pastures, while in pastures a number of types, varying in habit and growth period may be desirable. Different strains again may be required to meet the wide range of climatic and soil conditions. The practical question arises of when to stop producing new strains and concentrate on field tests and commercial distribution, though it may be advisable to leave the latter to another organisation.

Both with ryegrass and red clover, an extensive genetic programme has been initiated. From the standpoint of pure genetics both plants are difficult to work with and a systematic exploration of all the factors in evidence would tax the resources of the Station without promise of results of commensurate scientific value. The Sub-Committee therefore thought that some limitation might be desirable and advised a study of specific problems, e.g., hybrid vigour and self-sterility, which have practical value as well as scientific interest.

The work of the Station naturally leads to field-testing, bulking and the distribution of seed. These problems are perhaps still in an experimental stage: trials of method are in progress both at the Station and at the outlying selected farms. Professor Stapledon is trying to form growers' associations, but the position is difficult, and the problem of the best course to be adopted has been the subject of much discussion between the Sub-Committee and Professor Stapledon.

The work done at Aberystwyth has added greatly to our knowledge of the characteristics of common grasses and of their special value as pasture constituents. American methods of agronomy, adapted to English and Welsh conditions, have led to the dissemination among farmers of many useful " doctrines ".

Results have also been obtained by experiments in the feeding of sheep, both on the effect of plants on stock and of stock on plants. In view of the small area of the present herbage plots, the use of tethered sheep, or of sheep which are grazed for a few hours in hurdled pens, has been adopted. Indications have thus been obtained of wide differences in nutritive value between different species of crops and different treatments. But exact quantitative measures of stock-carrying capacity cannot be made till enough seed of the new strains is available to sow down fields which can be grazed in ordinary farm conditions and the live stock weighed.

Scottish Plant Breeding Station, Corstorphine.

The Scottish Plant Breeding Station was visited by a Sub-Committee of the Agricultural Research Council on the 19th July, 1935, when Mr. W. Robb, Director of Research, explained that work on the improvement of plants was going forward on cereals, especially oats, on herbage plants, chiefly timothy, cocksfoot and perennial ryegrass, and on swedes. Sea-plantains (*Plantago maritima*) are also being studied to obtain a measure of the variation found in a plant population in uniform environment.

Mr. Robb's work on oats has resulted in three new varieties, which are already in demand for different climatic and soil conditions. Other types are coming on, statistical analyses in randomised plots being made of the more promising new varieties. In barley an attempt is being made to raise pure lines from the mixed strain grown in the North as " Scotch Common." Dr. W. Black is breeding improved varieties of potato from inbred parents; one variety is now being distributed. He is also crossing with certain wild Solanum species, some of which are immune from blight. At a sub-station potato varieties resistant to virus are being sought.

Dr. J. W. Gregor's work on grass is concerned with pasture rather than hay crops, and several new and promising strains of soft-leaved cocksfoot, decumbent diploid timothy and perennial ryegrass have been selected for trial.

With swedes Dr. V. E. McM. Davey is studying inheritance of yield, dry matter percentage, shape and colour of bulb, bolting and disease resistance. Determinations of dry matter alone do not measure the feeding value of the roots with sufficient accuracy. For example, some Danish varieties resistant to finger and toe are too fibrous, and attempts are being made to get softer, but still resistant types.

The Sub-Committee were favourably impressed with the work going on, but considered that the Station was badly equipped, especially in buildings, which should be improved.

The John Innes Horticultural Institution.

The work at the John Innes Horticultural Institution on the cytology and breeding of apples, pears, plums and fruit of the genus Rubus (raspberry, loganberry, veitchberry, etc.), was continued without material change during 1934 and 1935. The cytological investigations were carried on by Dr. A. A. Moffett until May, 1935, when he left to take up a position in Southern Rhodesia and was succeeded by Dr. M. M. Richardson.

The work on pears systematically undertaken in 1934 indicates that the cultivated pears possess a similar, though not identical, complexity of constitution as the apples. Triploids are frequent and usually give little good pollen, but most of the diploids give a satisfactory pollen germination. Systematic examination of the pears has been begun in order to ascertain the most suitable varieties for interplanting. Several of the forms of Prunus commonly used as rootstocks for plums and allied fruits were found to be hexaploids and one a pentaploid. The chromosome constitution may have a bearing on incompatibility and bad unions between stock and scion. Polyploid raspberries were also studied. It is among the polyploid Rubi that the commercial berries of the future are to be expected; the loganberry is a chance produced hexaploid, whose constitution is being elucidated with the possibility of arriving at an analogous seedling of finer quality.

The work is of a fundamental nature, but it is an important complement of the fruit breeding investigations in progress at the Fruit Research Stations at Long Ashton and East Malling, with which collaboration is maintained.

Grants from the Council's funds amounting to £500 in the two years were made for the prosecution of these investigations.

HORTICULTURE AND FRUIT RESEARCH.

In the last Report of the Agricultural Research Council, accounts were given of the John Innes Horticultural Institution, of the Horticultural Research Station, Cambridge, and a preliminary statement was made about the Glasshouse Crops Research Station at Cheshunt.

The Horticultural Research Station (Glasshouse Crops), Cheshunt.

The Cheshunt Station was further visited by a Sub-Committee on the 22nd June, 1934, when the work was fully described by Dr. W. F. Bewley and his staff. The Station is well supported by the industry, over 160 new members having paid subscriptions in 18 months. Part of the membership income is being used to reduce an overdraft which hampers the activities of the Station.

A marked increase of interest in glasshouse cultivation is going on, new developments being specially noticeable in the growing of winter vegetables, in which the Station is playing a leading part. As mentioned in the last Report, a new lettuce has been produced which matures early and produces solid hearts during the short daylight of winter. Seed of this variety has been grown in Italy, and it was hoped to have an appreciable amount for English greenhouses during the next winter.

Dr. Bewley has published a book on mushroom growing, and work is in progress on the control of the diseases and pests of roses and on other side lines, though the chief attention of the Station is still given to tomatoes and cucumbers, on which important progress can be reported. The control of tomato and cucumber mosaic disease by the use of clean seed and by the early rogueing of diseased plants has been widely adopted by growers with excellent results, as has the renovation of exhausted soil by the addition of straw and the improvement of the growth of tomatoes by soil heating. Fertilizer tests are also going on with well marked effects. These and other experimental results are examined for significance by the Statistical Department at Rothamsted.

It was pointed out by Dr. Bewley to the Sub-Committee on Insecticides and Fungicides, whose Report is referred to (p. 43) below, that the problems of the control of insects and fungi in glasshouses are different from those in fields and orchards, and no work is being done on them elsewhere in this country. Tentative experiments have given good results, but cannot be followed up for want of time and staff. This is a cause of discontent among growers, and the Sub-Committee recommended that the work be made a recognised branch of the activities of the Station.

All the glasshouse work, the Sub-Committee reported, is directed to the solution of definite problems and bears the stamp of an eminently practical as well as a sound scientific direction. They recommended that increased financial support be given to the Station.

East Malling Research Station.

The Horticultural Research Station at East Malling, Kent, was described in the last Report. A Sub-Committee continued the inspection in 1934, with special reference to the position of that part of the work previously supported financially by the Empire Marketing Board.

The Sub-Committee found that no section of the work could be picked out as specifically concerned with problems peculiar to the overseas Dominions. The investigations all deal with the general problems of fruit growing in temperate regions, and, in those regions, are of universal application. Practically all the work calls for co-operation of the different departments, and the Station shows an exceptionally favourable example of team work. No branch of the work could justifiably be eliminated. Good contacts are being maintained with Long Ashton and other Stations.

The great development of fruit growing now going on, fostered by the new national policy, is coloured throughout by the work of East Malling and Long Ashton, and would have been far less effective had these Stations not existed. The calls on them for information and advice are continually increasing, both from this country and the Dominions overseas.

Research Station, Long Ashton, Bristol.

The Long Ashton Research Station, near Bristol, was visited by a Sub-Committee on the 16th and 17th November, 1933, and their Interim Report was adopted by the Plants and Soils Committees and by the Council.

The dominant feature of the work of the Station is the study of the nutrition of the fruit tree and the effect of soil, fertilisers, cultivation, stocks and other factors on the intake of the plant constituents. Though grants, both for capital outlay and annual expenditure, had been received from the Empire Marketing Board, none of the investigations going on could be specifically reckoned as overseas problems, nor could any of them be dropped or deferred without injury to the general programme of research carried on for the benefit of the home industry. The Sub-Committee therefore advised that funds should be found from other sources to support the work hitherto financed by the Empire Marketing Board.

They considered too that there was no wasteful overlapping of work as between Long Ashton and East Malling. Such repetition as there is represents only the necessary enquiry as to the difference of response in the climatic conditions of the western fruit growing area as compared with those of the eastern. The Station had already effected all economies that are possible without impairing its essential programme of work in response to the reduction of grant made in 1932.

The whole of the work of the East Malling and Long Ashton Stations is now being examined more exhaustively than was possible on the previous occasion, when immediate advice was required as to what grants formerly provided from the Empire Marketing Fund should be continued.

Fruit and Vegetable Preservation Research Station, Chipping Campden, Gloucestershire.

The Station at Chipping Campden for Research into the Preservation of Fruit and Vegetables was visited by a Sub-Committee on the 15th September, 1933. While the chief work is devoted to the problems of the canning of fruit and vegetables, a Dairy Section had recently been established to study the canning of cream and cheese. There is a Committee of Management established by Bristol University and a Technical Advisory Committee, on both of which are representatives of the canning industry. Thus close touch with practical questions is maintained.

The work includes the study of the varieties of crops most suitable for canning, of methods of cultivation and harvesting, the design of suitable containers, the methods of processing different products and the faults developed in stored produce.

Advice is given in all these subjects to large numbers of enquirers, as well as on business methods.

The Director, Mr. F. Hirst, at the time of the visit, was engaged in investigating certain faults in canned peas and had recently published a paper on " Flat Sour " spoilage caused by thermophilic bacteria. The recent large development in the growing and canning of peas may be said to have been made possible by Campden, where a harmless process of greening, so as to reproduce the natural colour of the pea which is lost in canning, was discovered.

Messrs. W. B. Adam and G. Horner were studying the changes that occur in peas during ripening. In some varieties the change from sugar to starch is fast and in others slow. A slow change is desirable, for it makes possible a longer harvesting season.

Some varieties or lots of strawberries in both England and Scotland, though canned whole, fall to pieces in the process. The fault has been traced to a new fungus identified by Miss M. Olliver, one of Messrs. Chivers' technical staff, with the help of Mr. F. T. Brooks and Mr. J. Ramsbottom, and named *Byssochlamys fulva*. Nothing was known about the source of infection. The subject is one of both scientific interest and practical importance, and grants of £476 in all over a period of two years for work on the fungus were made by the Agricultural Research Council to the Imperial College of Science and Technology in response to a joint application by the College and the Chipping Campden Station.

Mr. J. Stanworth has designed apparatus for measuring temperatures and pressures inside cans, apparatus which is now in regular use. Other larger forms of apparatus have been lent by manufacturers.

Mr. N. B. McMaster is studying bitterness in canned cream, which is caused by a bacillus which liquefies the cream, and is at present of unknown identity.

The canning industry is divided into two sections, one consisting of large firms turning out cans of fruit by the million, and one of grower canners, some of whom work on a quite small scale. The Station has designed plant suitable for small growers, and helped in designing new types of cans, which are made by a combination of makers at Worcester and Acton, turning out about 120 million cans annually.

Hitherto the Chipping Campden Station has been reckoned as agricultural, and has been supported by grants from the Development Fund through the Ministry of Agriculture. The connection with other Stations concerned with food products, under the control of the Department of Scientific and Industrial Research has, however, led to the recent transfer of Chipping Campden to that body. In the necessary negotiations the Agricultural Research Council gave their assistance.

INSECTICIDES AND FUNGICIDES.

The importance of the injuries done to crops by insects and fungi led the Agricultural Research Council to appoint a Sub-Committee to report on the whole subject of insecticides and fungicides. They submitted a Report on the general aspects of the problem in April, 1934.

In 1928 a Committee of the Ministry of Agriculture and Fisheries, set up to give effect to a resolution of the Imperial Agricultural Conference of 1927, had recommended an ambitious scheme for the formation of a team of research workers at one centre to search for new toxic substances and investigate their effects. This scheme involved an expenditure of £46,000 in the first five years, and had to be put aside in the financial situation of the country.

The Sub-Committee of the Agricultural Research Council therefore confined their attention to the more pressing problems, fundamental investigations being only admitted when needed for the examination of some point of practical importance. Other questions, such as soil disinfection, were excluded for the time being owing to the narrow resources available. The work at Rothamsted and at Cheshunt is, in the view of the Sub-Committee, part of the normal activities of those centres, and was not considered to call for aid by special grants from the Council's funds. Thus the Sub-Committee was brought to decide that the pests and diseases of fruit offered the problems of most pressing interest for their immediate consideration, and they had full discussions with the staffs at Long Ashton and East Malling and with Mr. F. R. Petherbridge of Cambridge. At Long Ashton considerable progress had been made in the more fundamental matters, especially the fungicidal and phytocidal action of sulphur, the improvement of winter washes and of spray nozzle design. At East Malling less fundamental work had been done owing to the lack of staff, especially on the chemical side.

There is general agreement that the more pressing problems include the production and testing of suitable combinations which would control two or more fungal diseases and insect pests, the improvement of spraying technique, and the causes and avoidance of injury to the trees by the substances used.

The effects are different in the two climatic areas, and there is need for research in both. Among the questions to be studied may be mentioned an efficient bactericide for use against bacterial cankers and the leaf spot of plum and cherry, a non-poisonous dust to apply to apples just before picking to prevent tortrix attack during storage, a combined control of plum sawfly and red spider, a control of various strawberry pests and diseases, the insecticidal properties of nicotine substitutes, derris and similar materials, colloidal fungicides, spreading action, power machinery for dusting, and so on.

The Sub-Committee recommended that at Long Ashton a grant be made for an area of six acres to be set aside for spray tests. At East Malling the superior staff was inadequate for the work necessary, and a considerable addition to the staff was needed. In this way the Sub-Committee thought that immediate requirements should be met, but they held that the larger scheme of the 1928 Committee should be carried out when financially possible.

These recommendations were accepted by the Plants and Soils Committees of the Council and by the Council itself. Grants were made in 1934 from the funds at the disposal of the Council for the initiation or encouragement of special researches, amounting to £562 spread over two years to Long Ashton and £2,025 over the same period to East Malling. The work has made a satisfactory start and it is hoped that it will prove of value to the fruit industry, on which the cost of controlling pests and diseases is one of the heaviest charges.

The Sub-Committee visited the Insecticide and Fungicide Department at Rothamsted on the 20th April, 1934, and discussed matters with Sir John Russell, the Director, and Dr. F. Tattersfield, the Head of the Department. Since about 1920 the programme, developed from the pioneer work of Tattersfield and Fryer on derris root, has been chiefly devoted to three main fields:

(1) The study of the insecticidal properties of certain products of industrial chemistry and some plant products;

(2) A study of the insecticides found effective, with a view to their evaluation by chemical means and an understanding of their use;

(3) The effect of environment, manurial and meteorological, etc., on the potency of plants giving insecticidal products.

None of the synthetic chemical compounds has a potency approaching that of the natural products from derris or the pyrethrins. All the natural plant products of the derris type hitherto found effective come from plants of the family Leguminosae, and all contain rotenone or chemically allied substances. One of the best is a preparation known as " barbasco ", obtained from a species of Lonchocarpus in Peru, but Peru has placed an embargo on the export of living plants of this species.

Derris root varies greatly in its contents of rotenone according to its environment, and a study of this variability is being made with the help of the Department of Agriculture of Malaya, where the root is cultivated commercially. Pyrethrum of good quality can be grown in England and in Kenya, and in the latter territory a considerable industry is growing up. Dr. Tattersfield maintains contact with the growers and agricultural officials concerned, and with East Malling.

Dr. Tattersfield would have liked to extend his work to the more fundamental problem of the mode of action of the poisons on the insect, but the staff of the Department was inadequate, and could not be increased so as fully to meet this demand. But the Sub-Committee were impressed with the importance and success of Dr. Tattersfield's work, and recommended an addition which would meet more fully the needs of the present programme.

Very little work has been done in this country on the mechanics and physics of spraying. Mr. C. W. B. Wright and Dr. R. M. Woodman of Cambridge have measured the variation with pressure and the depth of the swirl chamber of the volume of liquid delivered through certain nozzles. Mr. C. Davies of Wye has begun an investigation on muzzle velocity and pattern as determined by pressure and the size of drops, and elaborated a method for recording patterns on discs suspended in trees in field conditions. Such work should finally enable the biologist and horticulturist to indicate to the machine maker or inventor the exact physical specification of the sprays they need. The Sub-Committee thought that encouragement should be given to Mr. Davies's work.

Towards the end of the period under review, the Sub-Committee considered proposals from Professor J. W. Munro of the Imperial College of Science and Technology for work on the physiological aspects of the action of toxic substances on insects. They decided to recommend to the Council that the work should be supported. The Council approved a grant of £900 (including £250 for non-recurrent expenditure) for this purpose during the academic year 1935-1936.

BIOLOGICAL CONTROL OF INSECT PESTS.

The biological control of insect pests by parasites is being studied at the Farnham House Laboratory of the Imperial Institute of Entomology. Hitherto such control has been empirical, but it is now hoped to attack some of the more fundamental problems involved. The Agricultural Research Council have made an interim grant of £250 for one year to maintain the work, till the Imperial Authorities can decide whether to continue it permanently.

VIRUS DISEASES OF PLANTS.

The survey of present researches on the virus diseases of plants by a Sub-Committee of the Agricultural Research Council, mentioned in the last Report, was continued.

The Sub-Committee visited the potato virus diseases section of the Station of the Scottish Society for Research in Plant Breeding at Corstorphine and the Sub-Stations at Ainville, Midlothian, and Huntly, Aberdeenshire, in September, 1933. The special buildings required by the section were finished in 1930, and the work began in 1931 with a grant from the Empire Marketing Board. The work is chiefly directed towards an analysis of the inheritance in potatoes of different degrees of susceptibility or resistance to virus diseases, with the ultimate object of discovering or producing immune varieties. Mr. E. C. Barton-Wright and the late Mr. A. N. McBain jointly carried out an extensive investigation of the carbohydrate metabolism of leaf-roll potatoes compared with that of healthy ones by analyses of leaf lamina and petiole at different hours of the day and different seasons, and in 1932 the work was extended to crinkle, and to nitrogen metabolism. The Sub-Committee thought that, while this part of the work was of interest, it was unlikely to lead to practical results.

The results of breeding on the susceptibility of the seedlings to virus infection have been studied at Huntly and Ainville. Owing to the almost complete absence of insect vectors at Huntly, and the facilities for isolation from field crops of potatoes at Ainville, it is possible there to keep seedlings from healthy stock free from disease and those carrying one disease free from secondary infection. Full use of this advantage is being made by Mr. G. Cockerham in a well thought out programme, all connected with the main problem of the inhertance of virus reaction. During the past year it has been decided to concentrate the virus breeding work at Ainville, leaving Huntly free for the growing of virus-free stocks.

The work of the Potato Virus Research Station, Cambridge, was described summarily in the last Report. Under the control of Dr. R. N. Salaman, helped by Dr. Kenneth Smith and others, the Station deals with diseases of the potato, carrying on both the study of viruses and the attempt to develop a race of potatoes immune from blight. (*Phytophthora infestans.*) The Sub-Committee have now studied the work in relation to that at other places.

Dr. Salaman is trying to maintain virus-free stocks for scientific purposes, and it seems possible that, if an area relatively free of virus or its vector could be found in which these stocks could be multiplied, the establishment of an important seed potato industry in England might be assisted. Certain areas in North Wales and Cumberland appear to be promising in this respect.

Dr. Salaman and Mr. F. C. Bawden were engaged on a study of " biotypes " of the group of viruses called X by Dr. Kenneth Smith, of which three have been separated. Dr. Kenneth Smith and Mr. J. P. Doncaster are concerned with the insect transmission of virus in potato, tomato and other plants, especially with the unknown method of transmission of the X type of viruses; work on the particle size of some potato viruses is also being continued. The spotted wilt of the tomato has been found to attack many other plants, and threatens to become one of the most dangerous infections in both private and commercial gardens. In sugar-beet a mosaic and a filterable virus, which causes only local lesions, are being studied. Dr. Kenneth Smith has also identified several undescribed viruses causing disease in ornamental plants both in the open and under glass, and has indicated methods of control whereby the incidence of infection may be reduced.

The Station is in touch with the work going on simultaneously at Rothamsted and in Scotland and Ireland, and has brought to Cambridge different types of virus, till an extensive collection has been accumulated to illustrate all potato viruses found in the British Isles.

If, as recent work indicates, there are several " biological races " of *Phytophthora infestans*, there must be great difficulty in raising varieties immune or resistant to them all, and the Sub-Committee recognised that a special assistant to help with this work was desirable. In general, they considered that the work done at the Station was extensive, and of high quality. They thought the work had been on the more experimental aspects of potato virus research, and should be supplemented there, or elsewhere, by an exploration of the commercial possibilities of the nucleus stocks now available.

The virus work at Rothamsted was examined by the Sub-Committee on the 12th October, 1933. It forms part of the activities of the Plant Pathology section under the control of Dr. J. Henderson Smith, and hitherto had been financed by the Empire Marketing Board. It is primarily directed to a study of the fundamental scientific problems underlying virus diseases, especially those concerning the virus itself, rather than to the direct attack on practical difficulties, which characterises the work at other Stations.

Much of the work has been done with the standard Aucuba mosaic virus, which has been maintained pure in tomato plants since 1926. Dr. J. Caldwell has separated a green and a yellow constituent of this mosaic, and in studying the relations between them he has repeated Salaman's protective inoculation, and shown that an inoculation with the green constituent will prevent the yellow from infecting. He has also attempted to free the virus from cell proteins, working with the large particled virus Hyoscyamus III.

Dr. F. M. L. Sheffield is working on her discovery that cell inclusions of a type regarded as characteristic of mosaic diseases can be induced by giving the plants a molybdenum compound or lactic acid. Leaf mottling can be induced by the same means. If the cytoplasmic instability that seems to be caused by virus infection can be brought about artificially, its control may also be possible and a method of controlling virus diseases may eventually be developed. Dr. M. A. Watson's work with insect vectors is largely devoted to developing more exact quantitative methods in the study of insect transmission.

It was clear to the Sub-Committee that the virus work at Rothamsted, which deals with fundamental scientific problems, is being carried out in an intensive, enthusiastic and critical fashion and is worthy of support.

Other Diseases of Plants.

Other diseases are also studied in the Plant Pathology Department at Rothamsted, which was visited by a Sub-Committee of the Council in 1934. The mycological laboratory from its erection in 1918-19 till 1932 was under the direction of Dr. W. B. Brierley, who gave most of his time to a detailed analysis of the fungus Botrytis. He has been succeeded as mycologist by Mr. G. Samuel, who will work mainly on soil fungi, both as agents of disease and in their mutual relations and antagonisms to one another.

Miss M. D. Glynne has specialised from 1920 onwards on the wart disease of potatoes, and has lately given some time to a survey of the incidence of certain fungi associated with the foot and root rot of cereals.

In the entomological laboratory since Dr. C. B. Williams became head in 1932, the main work has been an investigation into the abundance and activity of insects with a view to correlation with climatic conditions. Dr. H. F. Barnes has made a special study of willow midges and wheat midges, dealing with the causes of immunity of several varieties of willow from the former, and the marked periodicity in the prevalence of the latter from year to year. As a specialist on gall midges, he has much advisory work also.

The mycological and entomological departments were originally planned as a Phytopathological Institute, but they are now merged in the Rothamsted Experimental Station. The Sub-Committee, while supporting the need for long range fundamental research, held that there should be a close connection with applied science, the relation with agriculture being kept in mind. They thought that the immediate phytopathological needs on the side of horticulture were well met, in the various Institutes, but that more attention should be given to the applications of entomology and mycology to agriculture, probably elsewhere than at Rothamsted.

In July, 1934, a grant was made from the Council's funds to the Botany School of Cambridge University to enable promising work on the cause of the " chocolate spot " disease of broad and field beans, which Mr. A. R. Wilson, an Agricultural Research Scholar, was carrying out, to be continued by him after the expiry of his scholarship.

Mr. Wilson's earlier studies had led him to doubt that " chocolate spot " is due to the bacillus, *B. lathyri,* to which it had formerly been attributed, and had shown that typical symptoms of the disease could be produced by a Botrytis fungus. These results were confimed during 1934-5 and a study of the epidemiology of the disease was commenced. Fortunately, from the point of view of the investigator, 1935 was an epidemic year for " chocolate spot ", and extensive field observations were thus possible. A further year's work was considered desirable, mainly to follow up the study of the environmental and predisposing factors which lead to the development of the lethal form of the disease and thus conduce to epidemic outbreaks. For the two years the Agricultural Research Council made grants of £273 in all for this work, to supplement a Carnegie scholarship held by Mr. Wilson. The results have already thrown much light on the causation and epidemiology of this disease, which in bad years is capable of almost total destruction of field bean crops, and which had been previously much misunderstood.

A new disease was reported in March, 1935, to be causing severe losses to tomatoes grown under glass in the South-west of Scotland. The Agricultural Research Council made a small grant to the West of Scotland Agricultural College for a preliminary survey of the extent of the damage and the conditions that appeared to favour the disease. The survey was carried out by Mr. H. Ferguson, a graduate research student of the College, who submitted a report in October, 1935.

The disease was found to be almost restricted to the Clyde Valley and appears to be due to a soil fungus of the genus *Phytophthora.* Attempts to isolate the parasite were unsuccessful, but are being continued; further work will then be necessary to prove that it is the cause of the disease and to attempt to devise methods for its control. Preliminary work suggests that soil sterilization will prove an effective remedy.

The increasing prevalence of the root eelworm disease of potatoes, due to *Heterodera schachtii,* caused the Agricultural Research Council, at the instance of the Ministry of Agriculture and Fisheries, to call a conference early in 1934 to consider the desirability of furthering investigations on this pest. From the discussion at this conference it appeared that the biological work on the root eelworm then actively in progress at the Institute of Agricultural Parasitology of the London School of Hygiene and Tropical Medicine, under the direction of Professor R. T. Leiper, required to be supplemented on the chemical side. The earlier work is briefly referred to in the summary of a Report to the Council by a Sub-Committee which visited the Institute, contained in the section on Animal Diseases of this Report (p. 72).

The worm concerned had been found to hatch out from its cysts only when a special stimulus was supplied. Under natural conditions in a potato field this stimulus is provided by a root secretion. The possibility that some artificial substitute for the potato root secretion might exist, which could be applied to the soil as a dressing at a time of year when there were no potatoes in the field, required to be explored. If such could be found, the cysts in infected soil would hatch out and the worms would perish in the absence of their natural food, the potato roots.

A grant of £700 spread over two years was accordingly made from the Council's funds to the London School of Hygiene and Tropical Medicine in April, 1934, to enable the Institute to employ a worker to study this problem under the general supervision of Professor H. Raistrick, in whose bio-chemical laboratory at the London School he would work, while keeping in close touch with the Institute's field work at St. Albans. Dr. R. H. Hurst was selected to carry out the investigations. In his first year's work he succeeded in obtaining by alcohol precipitation fractions of the root excretion of potatoes that were active in causing the worms to hatch from the cysts at dilutions of one part in 500,000 of water. Further work is in progress with the object of isolating the active substance or substances. He also found that certain chemical compounds have the power of delaying hatching even in the presence of active root excretion. This may possibly have a practical application in view of the fact that workers in the Irish Free State have ascertained, from pot experiments, that if hatching can be delayed until the young potatoes have developed a fairly strong root system, the plants can withstand infection. Direct attack on the cysts in the soil by means of chemical disinfectants is also being tried.

The results obtained in the London School and at St. Albans reached a stage in 1935 when more extensive field and pot culture work was needed. To aid in this the Agricultural Research Council made a further grant from their funds of £1,150 spread over two years from August, 1935. Of this sum £250 was intended for the purchase of a portable greenhouse (to remain the property of the Council) to enable potatoes to be grown for experiments during the part of the year when they cannot be grown out-of-doors. The balance was for employment of a research assistant and for expenses of experimental cultivation.

Work is actively in progress at the Institute of Agricultural Parasitology on a number of other plant parasitic eelworms. It was seen by a Sub-Committee of the Agricultural Research Council which reported to the Animal Diseases and Nutrition Committees of the Council in January, 1934, and is briefly referred to in the summary of the Sub-Committee's Report given in the section on Animal Diseases of this Report (pp. 72-74).

MISCELLANEOUS RESEARCH SCHEMES AIDED BY THE COUNCIL

Rice Grass

In May, 1934, the Agricultural Research Council made a small grant of £50 to the East Anglian Institute of Agriculture, Chelmsford, for the continuation of experiments in Essex on Rice Grass (*Spartina Townsendii*). Experimental plantations of this grass had been established by Mr. J. Bryce, botanist at the Institute, with the aid of a grant from the Empire Marketing Board, in order to test its utility along the coast line of Essex in the prevention of coast erosion, for land reclamation and as a fodder plant. The grass grows well on the mud flats from high water mark down to a depth of six or seven feet below this point and, if not dislodged by currents, spreads naturally and binds the mud, gradually raising the level of the latter; plants from cuttings originally imported from England are systematically used in Holland for raising the level of "saltings" before building sea walls. Its uses in protecting against erosion are more limited, but in favourable situations it can help to keep out the sea and reduce the cost of upkeep of the sea walls.

Mr. Bryce gets many requests for advice on the establishment and management of this grass and the continuation of his observations and experiments was of value in extending his knowledge of these matters.

Varieties of the British Flora

The detailed studies of the variation induced in plants by growing them in contrasting types of soil, and of the natural range of variation and hybridization in certain British species, carried on by Mr. E. M. Marsden-Jones at Potterne in Wiltshire, were further supported by a grant of £100 from the Council's funds in 1934.

These studies are of much theoretical and practical value. They are intended, for instance, to throw light on the fundamental problem whether races of plants arise in direct response to the environment, e.g., the soil, or whether they are produced by selection from an initially mixed population. They are also aimed at obtaining a proper conception of the nature of a species and of the status of sub-species, varieties and the like. This side of the work is carried on in collaboration with Kew and with the John Innes Horticultural Institution.

The studies of strain origin are of importance in agriculture and horticulture. Among the plants tested in regard to their soil reactions are several species of fodder crops, and strains of these have been sent to Cambridge and Aberystwyth for trial. One of these, a strain of kidney vetch known as Amaranth Purple, has been tested at the National Institute of Agricultural Botany and shows promise of giving, on selection, higher yields than the present commercial stocks of kidney vetch. Selection within this strain is proceeding at the Cambridge Plant Breeding Institute and at Potterne.

V. ANIMAL HEREDITY AND GENETICS

Research into problems of animal inheritance and genetics in Great Britain is limited to a few centres, though the art of breeding for the improvement of strains is and has long been highly developed in this country. The two main Institutes concerned with this subject are the Institute of Animal Genetics, Edinburgh University, and the Small Animal Breeding Research Institute, Cambridge; general accounts of the work of these Institutes were given in the previous Report of the Agricultural Research Council.

The practical and scientific problems of pig breeding were discussed at the Conference on pig research convened by the Council in May, 1935. The National Pig Breeders' Association had felt some doubt as to whether the existing problems of pig breeders were sufficiently covered by current research. The Pig Husbandry Experiments Committee considered that additional genetic information, such as the inheritance of teat numbers, growth rate, streak thickness, etc., was desirable. At the Conference Dr. J. Hammond of the Animal Nutrition Institute, Cambridge, explained that information was wanted as to the inheritance of undesirable qualities as well as on positive problems, such as the improvement of the commercial value of pigs. Extensive co-operation was required for the study of the inheritance of qualities such as thick and thin streak, and also inbreeding was necessary to show up the bad characteristics and enable work to be undertaken on the means of obviating these by suitable cross-breeding.

Since work on the larger farm animals is expensive and slow, an inbred rabbit colony is maintained at the Cambridge Institute by Dr. Hammond and Mr. M. S. Pease to work out the fundamental principles concerned in fertility and growth. These can then be tested on the larger farm animals. The main problems in inheritance in course of solution in the rabbit colony in 1934-35 were the inheritance and cause of foetal atrophy (the main factor controlling fertility in pigs), the inheritance of teat number and weight of the mammary gland.

At the Institute of Animal Genetics, Edinburgh, the study of genetics in relation to live stock breeding is in the hands of

Mr. A. D. Buchanan Smith. The work on pigs was described by him at the Pig Conference. A compilation which he had made of the literature of pig breeding, comprising some 500 papers, showed that the British contribution was small relatively to that of Canada and Sweden. While there was still great lack of knowledge of the inheritance of qualities such as colour, it was now possible to breed for number of teats, prolificacy, etc. In Edinburgh the work was chiefly on gross differences with complete litters having a standardized environment, from sows that received standardized treatment. The variation in food consumption per lb. of live weight gain was found to be small in litters from the same boar and sow and seemed to be a matter of inheritance. There was also some evidence that anaemia had a genetic basis. Litter testing had been used to provide information for breeding stock, and Mr. Buchanan Smith thought it was a valuable means of standardizing type. The stock that had been thus built up by Dr. A. Calder, then of the Institute, was prolific, rapidly growing and economical in food consumption. Results confirming these were stated by Mr. A. H. Blissett to have been obtained at the litter testing station of the Rowett Research Institute, Aberdeen. Since September, 1934, an experimental pig recording and litter testing scheme had been organized in the counties of Aberdeen and Kincardine with the Rowett Research Institute.

The work on pig breeding at the South-Eastern Agricultural College, Wye, was described to the Pig Conference by Mr. V. C. Fishwick. Three characteristics that appeared to have a hereditary basis were under study, namely, disease resistance, quality of carcase and meal consumption. Further details of this work were given in Mr. Fishwick's programme, which was referred to the Agricultural Research Council by the Development Commission in September, 1935, and which had been, on the initiation of the Council, under review by the Pig Husbandry Experiments Committee earlier in the year. The main objects were to ascertain the effect of crossing Large White and Saddle-back pigs and to compare the commercial value of the first-cross pigs as against the pure breed. The work was planned on lines parallel to certain of Dr. Hammond's experiments with rabbits at Cambridge, and was to be carried out in co-operation with him, to provide data on the inheritance of some important commercial characters of the two breeds. Where desirable, the observations would be carried through to the bacon factory.

Further consideration of these proposals was referred to a Sub-Committee of the Animal Diseases, Animal Nutrition and Breeding Committees of the Council, which reported after the close of the period under review.

The main work of the Small Animal Breeding Research Institute, which continued under Professor R. C. Punnett during 1933-34 and 1934-35, is concerned with the problem of the nature of fecundity in fowls. The chief investigation in progress is the influence, if any, of the sex-chromosome on laying qualities. A small and independent side-line of enquiry concerns the nature of certain birds with plumage closely resembling silvers, but with the genetical properties of golds. In ducks the formation of the Dark Runner breed, which can be used to give a clear sex-linked result at hatching, as the Cambar breed does in chickens, is complete. A homozygous drake, which enabled this result to be achieved, was obtained in 1934. The production of a similarly sex-linked Dark Campbell breed is less advanced. In the Poultry Genetics section of the Institute of Animal Nutrition, Mr. M. S. Pease is using the Cambar breed for applied genetical work. The main object is to improve the breed for use in the poultry industry. This was sufficiently advanced in 1935 to warrant limited distribution. The Central Committee for Agricultural Research Institutes, Cambridge, agreed with the Management Committee of the Institute that no attempt should be made by the Institute to exploit the breed. They proposed that it should be distributed to other agricultural institutions with facilities for poultry work and to private breeders, but asked for the views of the Ministry of Agriculture and the Agricultural Research Council; both agreed to these proposals.

An interesting memorandum on poultry research at the Institute of Animal Genetics, Edinburgh, was submitted to the Agricultural Research Council by Dr. A. W. Greenwood in September, 1935. While the fundamental problem under investigation is sex control, as many phases as possible of sex-activity in the fowl are covered. Observational studies have been directed to secure a large body of data for a stock bred under standard conditions and an assessment of the range of variation in such a stock. These data have not yet been fully analysed. The experimental work is both genetical and physiological. In the former field the main characters at present under consideration are egg size (involving the development of a large and small egg strain and the crossing of these), persistency of production over more than one year with associated absence of moult, and intensity of production. The physiological studies are linked with the genetical in that they aim at studying the mechanism by which the genetical factor carried in the fertilized egg operates to produce the expression of a character in the progeny.

Among the subjects of more practical interest to which Dr. Greenwood has contributed are breeding for egg production, egg recording as a basis for selection of breeding stock, analyses of sex ratios, and the value of the progeny in relation to the age of the dam.

Other genetical work on poultry in progress at the Institute includes studies of the inheritance of plumage colour in turkeys and geese.

Of the stations established under the National Poultry Institute scheme, practical investigations in poultry breeding for egg production are carried on at Reaseheath and were described in the previous report of the Council. Breeding experiments on poultry for table use are in progress at the South-Eastern Agricultural College, Wye. These were referred to the Council for advice by the Development Commission in October, 1934. The main object was to investigate the possibility of breeding a 2½ lb. chicken to replace the small imported birds. Crosses for this purpose were made between Old English Game, Scottish Dumpies, Faverolle, Light Sussex, La Bresse, and White Wyandottes. By 1935 it was clear that most of these had failed to achieve their object, and arrangements were made to review the work by a special Sub-Committee appointed by the Animal Diseases, Animal Nutrition and Breeding Committees of the Council to examine the whole of the poultry work at Wye. This Sub-Committee reported after the close of the period under review.

Research in wool problems financed in part by grants from the Empire Marketing Board was carried on by Mr. W. C. Miller at the Institute of Animal Genetics, Edinburgh, until the Board was dissolved. It was continued, aided by grants from the Council's funds, until March 1935; these grants totalled £804 during the two years under review, but were not fully expended. The most important problem investigated by Mr. Miller was the percentage of kemp (coarse, short, brittle fibres) in the wool of sheep. Two main factors are involved, environment and genetic constitution. Work carried out with Scottish Mountain Blackfaces led to the development of a rapid method of surveying the percentage amount of kemp distribution throughout the breed, the general average working out at about 14 per cent. for forced breeding rams and 8 per cent. for ewes. Different grades of kemp production were found to occur (many sheep had less than 1 per cent.) and within limits to breed true, so that it should be practicable for the breeder to eliminate this condition. Other variations in fleece characters were also studied, as well as the occurrence of so-called " naked lambs ", that is lambs born with a very short or sparse birth coat, the production of open fleeces (which may be linked with sparse birth coat) and the physiology and mechanism of inherited deformities. It was proposed to extend these investigations to the Cheviot breed, but the work was terminated on the resignation of Mr. Miller to take up an appointment at the Royal Veterinary College, London.

VI. ANIMAL PHYSIOLOGY AND NUTRITION

In the previous Report of the Agricultural Research Council a brief account was given of the work of the two Institutes specially established for research in animal nutrition, that at Cambridge, set up under the 1911 scheme of the Development Commission, and the Rowett Research Institute, Aberdeen, which was opened in 1922. But research and experiments in animal nutrition are not confined to the two Institutes of which it is the major function. Feeding experiments on sheep are in progress at the School of Rural Economy, Oxford; on pigs at Rothamsted, at the Agricultural Colleges, Wye and Harper Adams, at the National Institute for Research in Dairying, Reading, and at certain Farm Institutes; on cattle at Reading and the Hannah Dairy Research Institute; on poultry at the National Institute of Poultry Husbandry attached to the Harper Adams College and at Wye.

Animal physiology is implicit in much of the research work at the two nutrition Institutes and the physiology of animal reproduction is an important feature of the work of that at Cambridge; Dr. F. H. A. Marshall's well-known work on the physiology of growth and reproduction is continuing at the Cambridge School of Agriculture. In addition there is a section of physiology at the National Institute of Research in Dairying, the physiology of reproduction is studied at the Institute of Animal Genetics, Edinburgh, and biochemists are at work on animal problems at the dairy research Institutes, the Ministry's Veterinary Laboratory, the Institute of Animal Pathology, Cambridge, the Moredun Institute of the Animal Diseases Research Association, Scotland, the Royal (Dick) Veterinary College, Edinburgh, and the Royal Veterinary College, London.

In October, 1934, the Animal Diseases and Animal Nutrition Committees of the Council had under consideration the calorimetric work on the metabolism of the pig, which had been in progress under Dr. T. Deighton at the Animal Nutrition Institute, Cambridge, for some years. During this period investigations had been carried out in the fasting metabolism of some 25 hogs; each of these was under observation in the calorimeter at a number of different ages, and the intake and output of energy as well as material were studied for pigs under different conditions and on different diets. Considerable variations were found, due apparently to individual differences; there did not seem to be any correlation by which the economical animal could be identified before experiment. After discussion it was suggested that the calorimetric work on pigs should be brought to a conclusion and the results published. That on poultry in the smaller calorimeter devised by Dr. Deighton should be developed, as there was a lack of knowledge of the metabolism of the fowl.

At the Conference on Pig Research convened by the Agricultural Research Council on the 31st May, 1935, it was stated that the Pig Husbandry Experiments Committee were agreed that much greater attention ought to be paid to the study of carcase quality in relation to feeding. The experimenters' interest in the past had been restricted to such questions as the rate of live weight increase and the efficiency of food conversion, and their interest had tended to cease with the final weighing of the pig and its despatch to the factory. With the coming of grading, however, it was necessary to go much further than this and to follow the pigs from birth to the breakfast table. This implied that a considerable part of the research should be carried out in the bacon factory following slaughter.

Dr. H. E. Woodman explained to the Conference that at Cambridge they were investigating the effect on quality and conformation of feeding rations with much higher protein content than is normally used. These trials were being conducted without regard to the economics of such feeding; protein was the flesh former, responsible for the laying down of lean in the body of the pig, and the aim of the experiments was to obtain knowledge of the fundamentals of the production of fat and lean. The rate of live weight increase and efficiency of food conversion were being followed for three rations containing, respectively, 12, 22, and 32 per cent. of protein-rich food; the last ration contained about 27 per cent. pure protein. When the pigs were sent for slaughter at 200 to 210 lb. live weight, a large number of measurements were made to determine the conformation of the carcase and the relation of lean to fat. These trials were being conducted in such a way as to make possible a direct comparison of the group-feeding method of experimentation with the method of individual feeding. In the post-slaughter work Dr. E. H. Callow of the Low Temperature Research Station of the Department of Scientific and Industrial Research was co-operating with the Institute of Animal Nutrition. Complementary to these large scale feeding trials, more precise metabolic experiments were being undertaken to find what was the maximum capacity of pigs of different breeds at all stages to convert protein into lean flesh.

Wider studies were contemplated at Cambridge into the factors influencing the production of all classes and types of pigs, so that it might become possible to produce any type of carcase desired.

On the Cambridge University Farm, under Mr. W. S. Mansfield, work was in progress on one hundred pigs to find out whether the pigs which graded best were the most or least economical to produce in terms of food fed per lb. of live weight gain. One-half of the pigs were fed up to appetite and the rest received a restricted ration. The carcase measurements in this case also were being made by Dr. Callow.

In the general plan of work of Dr. J. Hammond's physiological section of the Animal Nutrition Institute, the object of which is to study the way the body works to produce the animal products so as to be able to control these processes, it has been planned to study the growth and development of the different parts and tissues of the body of the bacon pig in order to obtain a knowledge of how the proportions are affected by different circumstances. In this connection Dr. Hammond has studied the factors affecting bacon and pork quality as linked with carcase measurements, rates of growth, etc.

At the Harper Adams Agricultural College pig feeding experiments have been carried out by Dr. C. Crowther for many years with the underlying object of providing information on which pig-feeders may base the most economical rations, having regard to the particular circumstances of the feeding stuffs market. The work has comprised the testing of the various accepted rations for pigs, and a study of the possibilities of reducing certain constituents or of using more economical substitutes for them.

Considerable work has been done at this centre on the protein requirements of the pig, with particular reference to the quantitative and qualitative requirements at different stages of growth. The effect of protein supply upon the proportion of lean meat in the carcase has been taken into consideration in connection with the wider study of the influence of food upon carcase quality. This aspect of the work has recently developed in co-operation with the Cambridge Low Temperature Research Station. The effect of food on such physical characters as length of side, thickness of fat at various points and thickness of lean, as well as its effect on the character of the fat (softness, etc.) and on the proportion of fat to lean are all under study.

The experiments in 1934 included tests of pure as against commercial meat meal added to the cereal ration, similar tests with whale meat meal, and a feeding-management experiment to compare feeding twice and thrice daily. The whale meal rations gave a very efficient food utilization. The influence of outdoor exercise and grazing on back fat measurement was also engaging the attention of Dr. Crowther.

The South-Eastern Agricultural College, Wye, had been mainly concerned with problems of pig rearing and of the feeding of the sow and her litter. The work has recently been in charge of Mr. V. C. Fishwick, who submitted proposals for a considerable extension of it in 1935. The Animal Diseases and Nutrition Committees of the Agricultural Research Council set up a special Sub-Committee to examine the pig husbandry experiments at Wye and Harper Adams. This Sub-Committee has not yet reported.

Work on the feeding and management of the sow and her litter of the kind being prosecuted by Mr. Fishwick is regarded by the Pig Husbandry Experiments Committee as of the most fundamental character. The Council's Committee on Swine Fever, etc., called attention in its First (Interim) Report to the economic losses from " unthrifty " young pigs and the importance of the first six weeks of their life from this point of view. Mr. Fishwick's work on this subject is directed to the following main objects: — (1) to ascertain the effect of varying the protein content of the ration of the nursing sow; (2) to study the reasons why some pigs reared better than others. The most critical period in the life of a pig is, he considers, the first three to six weeks; management over this period influences its whole subsequent development. Pigs badly reared during the initial weeks of life appear to produce excessive fat. The sow is not a good nurser and it is necessary to supplement the food of young pigs. Methods of doing this are being tested at Wye. Other work on pig nutrition proposed or already undertaken by Mr. Fishwick includes tests of the economy of running growing pigs out of doors at different times of the year; experiments to ascertain the effect of reducing the energy value of the ration during the second half of the feeding period; a study of the correlation, if any, between the weight at weaning and the thickness of back fat and flank; and feeding experiments with brewers' grains and sprouted barley.

At Rothamsted the work in progress on the quality of green fodder crops has been found to necessitate feeding experiments, since chemical investigations alone will not satisfactorily indicate quality in terms of food value. Pigs are used for this purpose.

Among the problems studied are the relative value of wet and dry feeding and of restricted and unlimited feeding; the effect of the state of division of the food; and the effect of exercise on bacon quality. Weight, grade and bacon factory reports are the criteria adopted.

Work on sheep nutrition aided by grants from the Council's funds, totalling £278 for the two years from the 1st October, 1933, is conducted at the School of Rural Economy, Oxford, by Professor J. A. Scott Watson and his colleagues. A further grant of £100 for the continuation of the work was approved in May, 1935. This work is based on the view that certain existing standards for fattening sheep are out of agreement with the average results of feeding experiments. The object of the earlier experiments was to determine the effect of successive increments of net energy on the live weight increases in fattening. In the first experiment in 1934, 48 sheep were used in four groups of twelve each, which received increasing quantities of flaked maize and linseed cake in addition to a uniform hay ration. The feeding was continued until it was judged that the same degree of fatness in each lot had been reached; the animals were weighed every three weeks. The results, which were carried through to the slaughter-house, were such as to throw doubt upon the main assumptions on which existing sheep-feeding standards are based. The live-weight increases were considerably above those predicted using Wood's standards as a basis.

A second experiment with three lots each of 11 sheep was then begun in which the general range of energy intakes was lower than in the first. In this series it was found that the energy intake was considerably lower in relation to the size of the sheep, which were not at an age of rapid fattening, than the previously published maintenance figure.

In the next experiment the first experiment was repeated and, in addition, green food (marrow-stem kale) was substituted for a proportion of the hay in a ration composed of hay and concentrates (flaked meal and linseed cake) in three further lots of 14 sheep each. The results confirmed the earlier experiments in suggesting that Wood's standard for maintenance energy requirements is substantially too high. On the other hand the experiments taken as a whole indicate that the energy cost of live-weight increase is considerably higher than has been supposed. The rations containing a proportion of green food were probably somewhat superior to those composed of hay and concentrates only.

These experiments are being continued and lead on to a further series in which the next step is the testing of the relative efficacy of rations of varying protein content, 10, 15, 20 and 25 per cent., and of the same with the addition of a small allowance of cod liver oil.

Dr. J. F. Tocher of Aberdeen has been carrying out work, with facilities provided at the Rowett Research Institute, on the influence of feeding on the composition of the blood and milk of dairy cows; this was aided by special research grants from the Development Fund. The work was continued for a final year during 1933-34 on the advice of the Agricultural Research Council, the cost being met out of the budget of the Rowett Research Institute.

The general object was to find the cause of the low fat and solids-not-fat percentages in milk samples from certain cows and if possible to find a practicable method of improving the milk production and of raising the solids-not-fat percentage in the milk. So many have worked in this field with negative results that it is not to be wondered at that the results in this investigation were also, in the main, negative. The outstanding feature was the consistency of the milk constituents. Even when the ration of already poorly nourished cows was reduced there was no further fall either in yield, fat, or solids-not-fat. The change over from poor winter rations to good pasture was followed by a rise in yield, but none in fat and little in solids-not-fat. Feeding carotene in the form of carrots did not affect the composition of the milk, nor did an increase in the Ca and P content of the ration beyond causing a slight increase in ash content. A 30 per cent. increase in protein did not alter the fat percentage but seemed to increase the solids-not-fat. A ration rich in carbohydrates produced no significant change in the fat but a decrease in solids-not-fat. The fact that lactose, casein, albumin and globulin contents of the milk did not change from one lactation to the next is held to show that the variation in feeding had no permanent influence on the composition of the milk.

Less work was done on blood composition, but no relationship between food ingested and blood constituents was noted.

The quantity and composition of the milk secreted did not influence the total nitrogen, sugar, serum Ca and Mg and inorganic P of the blood; no relationship could be detected between blood sugars and lactose content of the milk.

Though the results of this laborious and thorough investigation were mainly negative, the Council were fully satisfied that it was well worth carrying out.

Nutritional work on poultry was only briefly referred to in the Council's first report. Certain aspects of it were considered in greater detail during the two years now under review.

The Council reported to the Ministry of Agriculture and Fisheries in December, 1933, that a special Sub-Committee which visited the Institute of Animal Nutrition at Cambridge had seen the work on poultry nutrition (fat formation in eggs and poultry) carried out by Dr. E. M. Cruickshank under a grant from the Empire Marketing Board. Her investigations on fat metabolism were considered to promise results of considerable interest; the problem she was attacking was of undoubted importance to the industry; and it was recommended that her work should be continued after the dissolution of the Board. This recommendation was carried out. Dr. Cruickshank is studying the nature of the body and egg fat; the extent to which these can be modified by dietary variations; and the effect on the quality of the fat of feeding large amounts of certain cereals and of the addition to the ration of oils of markedly differing chemical composition. Her work forms only part of the general scheme of research of the Poultry Nutrition Section of the Institute under Mr. E. T. Halnan, the programme of which has, since its inception, been subject to the approval of the National Poultry Institute Advisory Committee, a body on which the poultry industry is represented. The main function of the Section is a study of the nutritive requirements of the growing chick and the laying hen. The Section also is involved in a considerable amount of advisory work. Among the problems studied are digestibility of the commoner feeding stuffs, changes in composition during growth of a typical egg production breed and a meat production breed, protein and energy requirements for egg production. The development of Dr. Deighton's calorimetric apparatus for this last purpose has already been mentioned and a field experiment is also contemplated to obtain data from birds fed individually under commercial conditions. Mr. Halnan has started a preliminary study of the growth reactions of chicks to foods of a single origin.

At the National Institute of Poultry Husbandry at Harper Adams Agricultural College problems of poultry (meat and egg) production are under study. Grants were received from the Empire Marketing Board for this work and, when the Board was dissolved, the Agricultural Research Council were consulted as to their continuance. After consideration and discussion with Dr. C. Crowther (Director), Mr. A. J. Macdonald (Deputy Director) of the Institute, and with representatives of the

Ministry, the Council considered it to be highly desirable in the interests of the United Kingdom that the work hitherto financed by the Empire Marketing Board should be continued as part of the normal programme of a National Institute of Poultry Husbandry. In recommending the adoption of the programme of work for 1935-36 the hope was expressed that a Committee of the Council would visit Harper Adams College to examine it in detail during the coming academic year.

At the South-Eastern Agricultural College, Wye, poultry feeding experiments in the production of the crammed Surrey chicken have been in progress for some time, as part of the National Poultry Institute's scheme of experimentation and research. Recently battery brooders have been provided, and experiments were started to compare the results obtained in these with the older methods and combinations of the two. Experiments were also undertaken to be of use to the small rearers who cannot afford to employ a crammer.

In October, 1934, the Animal Diseases and Nutrition Committees of the Agricultural Research Council appointed a Sub-Committee to examine the experiments at Wye, in response to a request from the Development Commission to the Council for advice regarding the work. The Report of this Sub-Committee was not received until after the close of the period under review.

At the Rowett Research Institute poultry feeding experiments are in progress under a Joint Poultry Research Committee for Scotland and Northern Ireland. They are carried out on large groups of poultry with a view to determine their requirements for proteins, minerals and vitamins under different systems of management. Work on the physiology of the fowl has been carried on chiefly in the direction of studying the calcium, phosphorus and carbohydrate metabolism and the controlling influence of the ductless glands over the changes which take place in metabolism at different periods of the year.

Many aspects of fowl physiology are under investigation by Dr. A. W. Greenwood at the Institute of Animal Genetics, Edinburgh University. The Agricultural Research Council invited Dr. Greenwood to supply them with a summary of his work and they received from him a very interesting report in September, 1935. Much of the work is based on the fundamental problem of sex control and though not directly concerned with those functions of the fowl which make it of economic importance, gives expression to the view that the problems of the industry cannot be satisfactorily solved until knowledge of the fundamental basis of the economic characters is complete. The physiological studies are directed towards an analysis of the reproductive functions, many of which underlie egg production. In these, studies of the interaction of the ductless glands are included, and also analyses of the variation of body weight and of number, size and shape of eggs with age.

In November, 1934, the Animal Diseases and Animal Nutrition Committees of the Council submitted a Report on the proposals of the Department of Agriculture for Scotland for the development of research in animal pathology in Scotland. One of the recommendations in this Report was the appointment of a full time Professor of Physiology at the Royal (Dick) Veterinary College; in common with other members of the College staff, it was considered to be most desirable that the Professor of Physiology, when appointed, should have time and facilities for developing research in the College into problems of animal physiology.

In the previous Report of the Agricultural Research Council, reference was made (on page 97) to the establishment of a Central Committee for the general control of the Agricultural Research Institutes at Cambridge. This Committee submits with comments to the Ministry of Agriculture and to the Agricultural Research Council the estimates, programmes and reports of the various Institutes. As the Council was in large measure responsible for suggesting the enquiry which led to the setting up of this Committee, it is gratifying to note that the Central Committee appears to be fulfilling a very useful function in co-ordinating the agricultural research work in progress at Cambridge and in helping to secure that the best value in the advancement of scientific knowledge and in practical achievement is obtained for the State aid given to the Institutes.

Nutrition and Disease.

There has been ample evidence during the past few years of a wider recognition of the vital importance of nutrition in relation to health. This importance is not less in animals than in mankind and it has engaged the close attention of the Agricultural Research Council on many occasions. In November, 1934, the Council asked their Animal Diseases and Nutrition Committees to consider the question of the extension of research into nutrition in relation to disease and these Committees appointed a special *ad hoc* Committee in February, 1935, to consider the subject and to make recommendations.

Early contact was established with the Medical Research Council in order to consider the establishment of a Joint Committee of the two Councils to examine the fields of work that might be most desirable to expand. Not only have investigations of the effect of nutrition on health in large animals and man a common basis of experimentation on small animals, which can be easily and relatively inexpensively employed in large numbers, but many of the fundamental problems of the effect of unbalanced nutrition or of deficiency in vitamins and the like are in some degree common to the larger animals and man.

This joint interest had been early recognised by the establishment in 1932 of a Committee on Iodine Deficiency and Thyroid Disease composed of representatives of both Councils. Based on a method for the measurement of small quantities of iodine developed by Mr. C. O. Harvey of the Government Chemist's staff, work, which had been in abeyance for the lack of such a method, was renewed at the Rowett Research Institute by Miss G. Mason in 1934. The earlier work had been largely concerned with medical aspects of iodine deficiency; Miss Mason's tests of the new method of determining iodine in the laboratory specially set up for the purpose at the Institute showed that it would be possible to extend the work on the agricultural side. The Joint Committee recommended, at a meeting on the 30th September, 1935, that research should be continued on the agricultural side, as there were indications of an iodine deficiency problem in animals in Great Britain. Dr. H. H. Green of the Ministry's Veterinary Laboratory at Weybridge is carrying out observations on the clinical signs of iodine deficiency, especially in young pigs and lambs, and collecting material for examination by Miss Mason.

This is only one of several instances where it is clear that there is a common field in the study of human and animal nutrition in its bearing on health. Nutritional anaemia due to a deficiency of iron is a serious disorder in young pigs and is one of the main features in the type of "pining" in sheep prevalent in parts of Scotland. Dr. H. H. Green of Weybridge is investigating magnesium deficiency in co-operation with the Institutes at Moredun and Cambridge. Work on phosphorus deficiency is in progress at the Institute of Animal Pathology, Cambridge. There is evidence also that in the larger animals improper feeding heightens susceptibility to invasion by internal parasites and to infectious diseases such as tuberculosis. The Sub-Committee that visited the Institute of Agricultural Parasitology reported in January, 1934, that they had seen preliminary experiments in progress in order to test the effect on susceptibility to internal parasites of diets deficient in Vitamin A or in mineral salts; these were being carried out with pigs and poultry.

The enlargement on the medical side of the Committee of the Agricultural Research Council referred to above was agreed on, in consultation with the Medical Research Council, after the close of the period under review.

VII. ANIMAL DISEASES

The preponderance of attention given to the subject of animal diseases during the first two years of the existence of the Agricultural Research Council has been continued during the second two years. Committees, Sub-Committees and Special Committees concerned with animal diseases have met frequently, and, of the total of £23,388 granted by the Council for special researches, a sum of £12,185 has gone to work on animal diseases.

THE TRAINING OF INVESTIGATORS.

The preliminary problem of training men for research has been met by the awarding of two studentships in animal health in 1934 and of two studentships in 1935. It has become evident during the four years that the studentship scheme has been in operation that it is difficult to attract a sufficient number of candidates with the necessary qualifications to provide an adequate body of good research workers in animal diseases. The competing needs of other fields of veterinary science and practice, which offer greater material advantages, have reacted unfavourably on the supply of qualified men keen on research work. The Agricultural Research Council have asked the Agricultural Departments to take into consideration with them the possibility of an extension of the training scheme, whereby a limited number of men who have obtained high honours in pure science should be awarded studentships to enable them to complete a course leading to a veterinary qualification. The difficulty of obtaining men fit to undertake research in animal diseases is very real; indeed important work is being held up or not begun because suitable men to do it cannot be found. If the needs of the situation are to be met, new inducements must be offered to able young men to take up a career of veterinary research. In the view of the Agricultural Research Council the matter is urgent. Closely connected with the problem of staffing research is the wider problem of veterinary education in general. During the past two years the Agricultural Research Council has borne this question continually in mind.

THE ROYAL VETERINARY COLLEGE, LONDON.

The rebuilding of the Royal Veterinary College at Camden Town has proceeded and the building of the central College block is now well advanced. It is hoped that the re-building scheme may be completed in 1937. At a meeting on the 7th March, 1933, members of the Agricultural Research Council's Committee discussed with representatives of the Royal Veterinary College the Ministry's scheme for developing the Research Institute in association with the Department of Pathology in the College. The representatives of the College, as recorded in the Council's last Report, communicated to the Committee their complete proposals for re-organising all the departments of the College for teaching and research. In view of the direct bearing of these proposals upon the facilities and staff available for research, the opportunity was taken of considering the scheme as a whole, though the Council is not charged with duties relating to education. After prolonged discussion with the College representatives, the Agricultural Research Council's Committee recommended certain changes in the scheme, which they thought would conduce to greater efficiency and greater economy. These proposals, described in the Council's first Report* (p. 123), were fully considered by the College and the Ministry, but they can only be carried into effect gradually as funds and men become available.

ROYAL (DICK) VETERINARY COLLEGE, EDINBURGH.

At a meeting of the Agricultural Research Council on the 14th November, 1934, the First Report of their Animal Diseases and Animal Nutrition Committees upon the proposals of the Department of Agriculture for Scotland for the development of research in animal pathology in Scotland was adopted. It is stated in this Report that, in the opinion of the Committees, the strengthening of the staff of the Royal (Dick) Veterinary College in Edinburgh is of great and primary importance. Part of the object of the proposals is to give more time for research to the teaching staff of the College, and thus the Agricultural Research Council is directly interested. Conversely, it is hoped that some members of the staff of the Animal Diseases Research Association at Moredun may take an increased part in the advanced teaching of subjects upon which they are experts, so that education and research may be linked more closely together.

A scheme for increase of staff, prepared by the Authorities of the College, was brought into the joint consideration of representatives of the College and of the Agricultural Research

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* Report of the Agricultural Research Council for the period July, 1931—30th September, 1933 (Cmd. 4718).

Council. Modifications were thus made and an agreed scheme prepared, in which the new posts to be created were placed in order of priority. Arrangements for implementing this scheme have been begun with the aid of increased grants from the Department of Agriculture for Scotland.

Towards the end of the time under review, a plan for enlarging the buildings of the Royal (Dick) College was worked out, and an application for financial assistance was submitted to the Treasury by the Department of Agriculture for Scotland. The Treasury, on the recommendation of the Development Commissioners, have sanctioned the offer to the Governors of the College of a grant of £20,000 on the £ for £ principle in aid of this building scheme.

SCOTTISH BOARD OF RESEARCH IN VETERINARY SCIENCE.

In the last Report mention was made of the negotiations which had been begun with a view to bringing into the closest possible collaboration the staffs of the Royal (Dick) College and the Animal Diseases Research Association at Moredun. As there stated, both bodies agreed to refer the matter to the Research Committee of the Animal Diseases Research Association.

That Committee reported in 1934 and, in accordance with their recommendations, a Scottish Board of Research in Veterinary Science, of which Professor T. J. Mackie of Edinburgh University is Chairman, and Dr. J. Russell Greig, Director of the Moredun Institute of the Animal Diseases Research Association, is the Scientific Secretary, has been established. By its constitution the Board is to consist of fifteen members, seven nominated by the Directors of the Animal Diseases Research Association, six by the Board of Governors of the Royal (Dick) Veterinary College (of whom at least one shall be a member of the Senatus of the University of Edinburgh), one by the Scottish Branch of the National Veterinary Medical Association, and one by the Department of Agriculture for Scotland. In the main the members are to be men of science and nominations are subject to the approval of the Department of Agriculture. There is power to co-opt not more than two additional members. The Board is responsible ultimately to the Department of Agriculture and the Agricultural Research Council and its primary functions are to co-ordinate, control and supervise schemes of veterinary research in Scotland, to promote the advancement of knowledge in veterinary science and to encourage a close relationship between veterinary education and research. The Board is not concerned with the internal administration of the Institute or the College. The constitution of the Board is subject to revision at the end of three years.

The Agricultural Research Council welcome the establishment of the Board as an important link between them and those engaged in veterinary education, research and practice in Scotland and as an organisation which should do great service in ensuring the fulfilment of the Council's aim, to use to the best advantage for the development of research and education in Scotland the available funds, facilities and staff. The Council have already received from the Board valuable assistance in examining proposals for strengthening the staff and improving the accommodation of the Animal Diseases Research Association, in supervising research into bovine mastitis and in extending investigations into certain disabling diseases of horses.

INSTITUTE OF AGRICULTURAL PARASITOLOGY, LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE.

In January, 1934, a Sub-Committee reported on visits paid during the previous June to the Institute of Agricultural Parasitology of the London School of Hygiene and Tropical Medicine and its field station at Winches Farm, St. Albans.

The work falls into two main divisions—that on eelworms which are plant parasites, and that on the worm parasites of animals, especially sheep and poultry.

The plant parasitic eelworms are nematodes of the genera *Tylenchus* (*Anguillulina*), *Aphelenchoides* and *Heterodera*. They are being studied in the laboratory and by experiments in pot culture, small plots and field plots. The objects are the extension of knowledge of the biology and rate of spread of the worms, their specificity as regards host plants and the possibility of cleaning ground from infestation by the rotation of crops and by other means. One of the most interesting of the practical results is the discovery by Dr. Marjorie Triffitt that the infective larvae of the *Heterodera schachtii* of potatoes are activated by excretions from the roots of potatoes and grasses. By treating infected soil with water collected from a sand bed in which potatoes are growing, it is possible to cause all larvae to hatch from the cysts in which they are contained. If there is no suitable host plant present, the larvae die and the soil is cleaned. Certain grasses also secrete a substance which liberates these larvae and thus the rate of exhaustion of the cysts is accelerated. The further study of the important biochemical problem thus indicated has been taken up by the biochemist appointed in 1934 under a special grant from the funds at the disposal of the Agricultural Research Council and is referred to in the section on Plant Diseases of this Report (pp. 50, 51). Other eelworm infections of plants are also being studied, including the Tulip Root disease of oats, the strawberry eelworm (*Aphelenchoides fragariae*), the black currant eelworm (*Anguillulina ribis*), and the strain of *Anguillulina dipsaci* that attacks potato tubers. These problems are being investigated by Dr. T. Goodey.

The relation between helminths and insects is of interest. It is possible that some species of injurious insects might be controlled by worm parasites, and studies on nematode parasites of flea beetles with this object in view were being carried out by Dr. J. N. Oldham at the time of the Sub-Committee's visit.

The farm animals whose parasites are under investigation are sheep, goats, pigs and poultry. Goats are largely used instead of sheep, as being easier to manage under the conditions on the farm and as they are susceptible to exactly the same helminth parasites. Experiments are going on: (1) to test the survival of infective larvae in pastures; (2) to test increasing immunity with age in initally worm-free goats; (3) to test the influence of rotational grazing on the infection of sheep; (4) to test the effects of malnutrition due to deficiency of mineral salts or of vitamin A on susceptibility to infection in pigs and poultry.

Worm-free goats are reared by hand from birth to weaning and then kept in clean surroundings and fed on clean food. Such animals, which are difficult to produce in number, form the essential basis of all experiments. In the rotational grazing plots the experimental sheep rapidly acquire a much higher infection than the controls. But the number of sheep used is comparatively small and, as they may vary in the ease with which they become infected, the Sub-Committee thought the experiments might with advantage be repeated on a larger scale in some other area.

Other experiments both indoors and in the open air are directed to the study of the specificity of various nematode parasites of game, wild birds and poultry and the possibility of their transference from one to another. A stock of living specimens of the more important parasites of sheep is maintained in goats, and many worm parasites of animals are also maintained in dogs and rabbits.

The experimental work at Winches Farm bears testimony to the enthusiasm of the staff; it covers a very wide field of agricultural problems, which are correlated with complementary laboratory investigations in the London School.

The Report of the Sub-Committee was adopted by the Animal Diseases and Nutrition Committees, who themselves reported to the Council on the 14th November, 1934. They surveyed the whole work of the Institute of Agricultural Parasitology, and the development of that work on the side of helminthology proposed by the Ministry of Agriculture and Fisheries in a Memorandum on the re-organisation of animal diseases research in England and Wales submitted to the Council in 1931, upon which the Council had previously made four Interim Reports. The Committees discussed twice with Professor R. T. Leiper, the Director of the Institute, the increase in staff which would be necessary, and made recommendations. The Agricultural Research Council consider the main work on the fundamental problems of helminthology should be concentrated at the Institute of Agricultural Parasitology and the staff strengthened accordingly, at an approximate additional cost of about £2,000 during the first year, and a little more thereafter. The necessary financial arrangements for the gradual strengthening of the staff have been approved.

In order to initiate, as a special piece of *ad hoc* research, an intensive examination of various chemical substances for anthelminthic action against intestinal nematodes, especially those of sheep, the Agricultural Research Council agreed in 1934, upon an application from Professor Leiper, to grant £500 to the Institute of Agricultural Parasitology. Work on this subject was commenced at Winches Farm by Miss K. M. Sanderson, M.R.C.V.S., in August, 1935.

Special Researches.

In the Council's last Report the appointment was recorded of specialist Committees to enquire into the existing state of knowledge of certain diseases of animals, which seemed likely to spread, if the breeding of livestock was encouraged by the policy of His Majesty's Government, and to recommend what further investigations were desirable. A summary was given of the first recommendations of these Committees and it was explained that the funds of the Council were being used to supplement the existing resources of Institutions, so that urgent work might be extended under the general co-ordination of the Committees. Further Reports were received from some of these Committees shortly after the close of the period now under review and the general progress made may conveniently be considered now. A list of the members of the Committees will be found in Appendix II.

The Committee on Braxy and Braxy-like Diseases of Sheep.

It was stated in the Council's first Report that the preparation of a completely sterile vaccine from cultures of *Vibrion septique* for use as a protection against braxy was desirable, but that research on the relative immunising values of the more important constituents of the bacterial culture was necessary and was being undertaken at the Institute of Animal Pathology, Cambridge, the Moredun Institute of the Animal Diseases Research Association in Scotland and the Wellcome Physiological Laboratories at Beckenham. Recent work has shown that formolised whole cultures prepared according to a given technique constitute an effective vaccine. Though the view is widely held that *V. septique* is the organism causing the form of braxy prevalent in the North of England and in Scotland, there appear to be contributory aetiological factors. The Committee noted that at the Moredun Institute the question whether a physiological disturbance is associated with or precedes the invasion of the wall of the abomasum was being studied. The Committee found that attention was also being given at the Institute of Animal Pathology, Cambridge, and the Wellcome Laboratories to the study of the different toxins of the *Bacillus welchii* group, which includes the micro-organisms causing " pulpy kidney disease " and lamb dysentery. The Committee therefore felt that the chief need was to secure fuller and more accurate information in the field of the incidence of infections of sheep by anaerobic bacilli and of acute diseases of sheep of undetermined aetiology in Great Britain, and they recommended the appointment of a special research officer to undertake a survey, and to collect and examine material. It was agreed that while this officer might work from the veterinary laboratory nearest to the area which for the time he was examining, it would be necessary for him to have as his base a research institute, where specialised knowledge of anaerobic organisms was available.

The Committee decided that in the first instance the Institute of Animal Pathology at Cambridge should be the headquarters of the officer, who would carry on his investigations under the Committee's general supervision. Accordingly, a grant of £1,050 from the Council's funds was made available to the Institute for the financial year 1935-6. Some difficulty was experienced in securing the services of a suitable veterinary worker, but eventually Mr. R. S. Roberts, F.R.C.V.S., was transferred from the South-Eastern Agricultural College, Wye, to Cambridge.

The Committee had had under consideration a review prepared by their Secretary, Dr. A. D. McEwen, on the present state of knowledge of braxy and certain other anaerobic infections of sheep, and they obtained information from Veterinary Investigation Officers in England and Wales which showed that diseases similar to Scottish braxy occur in areas of North Wales, Northumberland and the East Riding of Yorkshire. Reports of the disease of lambs known as " pulpy kidney disease," probably similar to the disease of that name described in Australia and New Zealand and produced apparently by an organism of the *B. welchii* group, were received from Northumberland, North Wales and the Eastern Counties. This disease may well be closely related in its aetiology to lamb dysentery. A disease possibly of the same type affects ewes in North Wales; in East Somerset a disease of the " gas gangrene " type is described as causing a mortality up to 5 per cent. in sheep and lambs; from Shropshire and Devonshire diseases which could not be clearly defined were reported. Generally, it appeared that diseases due to anaerobic bacilli were prevalent in many parts of the country.

The Committee considered, however, that much more complete information regarding the incidence of braxy-like diseases of sheep was required and that assistance in collecting material in the field was also necessary. The co-operation of the National Veterinary Medical Association as well as of the Veterinary Investigation Officers was therefore enlisted, and the Council desire to acknowledge in the most cordial terms the valuable offers of help which they have received. It has been agreed that the laboratories of Veterinary Investigation Officers shall serve as centres for collecting information and examining material for their respective areas, and that the Institute of Animal Pathology shall be the central co-ordinating laboratory. Mr. Roberts, after spending a preliminary period at Cambridge, is assisting in the investigations in the field in areas where there are serious outbreaks of diseases of this type.

In January, 1935, Dr. Russell Greig made a preliminary report to the Committee on the extensive tests of braxy vaccine which were being carried out on farms in Scotland by the Moredun Institute. Except in intense outbreaks of the disease a single inoculation of vaccine had conferred a satisfactory immunity. Further large scale trials were made in 1935 and will be referred to in the Council's next Report.

A disease of sheep known as " struck " occurs in the rich grazing lands of the Romney Marsh, and is allied to those discussed above, in that it is caused by an anaerobic organism of the *B. welchii* group. On this disease Dr. A. D. McEwen of Wye College had been working for some time, and in 1934 the Agricultural Research Council made a grant of £60 to the College to enable him to extend his field experiments and to test on a large scale vaccination against the disease.

The Joint Committee on Tuberculosis.

The work on tuberculosis in animals at present proceeding in Great Britain is under the co-ordination of a Committee appointed jointly by the Medical and Agricultural Research Councils. Its chief centre is the Institute of Animal Pathology at Cambridge, where the main work is that referred to in the last Report of the Agricultural Research Council, on the testing of the Bacillus Calmette-Guérin (B.C.G.) vaccine as a protection from tuberculosis. In this work Professor J. B. Buxton, Director, and Mr. R. E. Glover, Assistant Pathologist of the Institute, are collaborating with Dr. Stanley Griffith of the staff of the Medical Research Council, who works in laboratories adjoining the Institute.

As an instance of the preliminary results obtained, it was found that calves vaccinated intravenously showed three months later a solid immunity to a test dose of the tubercle bacillus which produced marked lesions in the unvaccinated control animals; at six months the immunity was almost complete, at nine it was waning and it had almost faded at the end of twelve months. Re-vaccination at the end of six or nine months established a high degree of immunity, while calves re-vaccinated after twelve months were slightly less resistant.

The Animal Diseases and Animal Nutrition Committees of the Agricultural Research Council recommended in 1934 that the continuation of that part of these experiments which had previously been financed from a special Development Fund research grant made to the Ministry of Agriculture and Fisheries on behalf of the Institute should be a charge on the Council's funds. The Council accepted this recommendation and made a grant of £756 for the period from the 1st October, 1934, to the 31st March, 1936, additional to a grant from the Medical Research Council which expired on the 30th September, 1935. The experiments covered by these grants were directed to testing the persistence of immunity resulting from repeated injections with vaccine at six-monthly intervals up to three years, and to testing such animals by subjecting them to mild infection with known doses of the tubercle bacillus between each re-vaccination.

Further experiments with the B.C.G. vaccine at Cambridge at a cost not exceeding £3,194 during the year from the 1st April, 1935, to the 31st March, 1936, were approved by the Council in 1935. These experiments were intended to test the efficacy, over various periods, of B.C.G. vaccine in olive oil or paraffin and to carry out field tests of the vaccine. The preliminary results led to a considerable reduction in the expenditure incurred, as it was found to be unnecessary to carry on certain experiments on a large scale.

The Joint Committee on Tuberculosis set up a Tuberculin Sub-Committee in 1934 to report on the methods of applying the tuberculin test for cattle in relation to the scheme for "attested herds." The Sub-Committee held their first meeting in November, 1934, and subsequently submitted a report making certain recommendations and also stressing the need for experimental work to clear up several matters regarding which the evidence available was not sufficiently definite. It was recommended that the cost should be met from the money voted by Parliament for the scheme for the eradication of bovine tuberculosis. Work is continuing on this subject at the Ministry's Veterinary Laboratory at Weybridge and at the Institute of Animal Pathology at Cambridge.

For several years Lieut.-Col. E. C. G. Maddock has been carrying out investigations at the National Institute for Research in Dairying, Reading, in order to determine whether cattle could become infected by tuberculosis from grazing on pastures exposed to contamination with the tubercle bacillus. This work was assisted by grants from the Royal College of Physicians and the Agricultural Research Council in 1933. Further grants were made by the Council in 1934 and 1935 amounting to £447 in all. The earlier experiments had shown that the organism could still be found in a living condition in the soil and dung for a considerable time after an emulsion of it in water had been spread over the pasture. Later tests were designed to ascertain whether it was possible to infect calves by feeding them on pastures contaminated by infected animals, and the length of time the pasture remained infective when grazed. Though these experiments were not completed within the period covered by this Report, the evidence so far obtained indicates that under the conditions of the tests the new growth that comes up after the pasture has been grazed down has not caused infection in tubercle-free calves turned out to graze on it.

Contagious Abortion.—The Committee on Brucella Abortus Infection in Animals and Man.

In an Interim Report to the Animal Diseases Committee, dated the 26th October, 1933, the Special Committee stated that they had held six meetings and that they were co-operating with the Ministry of Health, who were represented on the Special Committee by Sir Weldon Dalrymple-Champneys.

Contagious abortion is a prevalent disease among cattle and produces heavy losses. *Brucella abortus* causes undulant fever in man, and the extent of infection in this country is now being estimated. It is probably not very great, but Sir Weldon Dalrymple-Champneys is engaged in collecting reliable statistics. Cases of undulant fever in Scotland are also being investigated by the Scottish Committee on Bovine Contagious Abortion in collaboration with the Department of Health for Scotland. A systematic study of latent infection in veterinary students is being made on behalf of the Scottish Committee by the Bacteriology Department of Edinburgh University. No simpler laboratory method of diagnosis than the agglutination test was available at the time of writing. Guinea pigs are the most suitable small animals for experimental work. The Committee found that a considerable amount of work was already going on.

The problem of immunisation is being attacked by means of investigations bearing on the production of a satisfactory dead vaccine at the Veterinary Laboratory of the Ministry of Agriculture, Weybridge, at the Research Institute in Animal Pathology, Royal Veterinary College, London, in the laboratory of the Veterinary Investigation Officer at the South-Eastern Agricultural College, Wye, Kent, and at the Animal Diseases Research Association, Moredun, Edinburgh. Methods have been carefully elaborated for assessing the degree of protection conferred by *Brucella abortus* vaccines in guinea pigs and in this way a beginning has been made in determining the actual immunising properties of different types of vaccine. Live vaccines are being tested at Weybridge and at Wye. An experimental eradication scheme, to be referred to more fully below, is in progress in collaboration with selected stockowners at a number of centres in accordance with a detailed plan drawn up by the Special Committee, with the help of the Scottish Committee.

The Special Committee held that more extended work on contagious abortion was necessary, and a majority thought that the only satisfactory scheme was one which involved the establishment of a farm centre under the direct control of the

Agricultural Research Council and the concentration there of most of the work, especially on large animals. This view was advocated in a detailed Majority Report, which pointed out that thus alone could the work be arranged on a sufficiently large scale, with an adequate area of land adjoining the special buildings, on cattle owned by the Agricultural Research Council and therefore under the Committee's full control. The work could thus be planned and be co-ordinated by one director at a single place. All the strains of Brucella in use would be tested by the same staff, who would devote all their time and thought to the investigation, and those responsible for the earlier experiments would also undertake the trials on cattle at pasture under more natural conditions. The scale of the experiments required would, the majority thought, interfere with other important research programmes, if the work were done at an existing Institute and would overweigh one side of that Institute's work. On the other hand, a Minority Report supported the opinion that the extended work could best and most cheaply be done at the existing Institutes, suitably enlarged, where already work on the subject is going on, buildings and plant are or would more readily be made available, and knowledge of technique has accumulated.

The Animal Diseases Committee decided by a large majority to support the Majority Report of the Special Committee and the Agricultural Research Council adopted it unanimously on the 6th February, 1935. After further consideration of the alternative proposals with the Agricultural Departments, the matter was referred to the Committee of Privy Council. The Committee of Privy Council in February, 1935, accepted the need for a large extension of the work on contagious abortion, but left the details to be settled at a later date. The Committee also held that the question of the powers of the Agricultural Research Council was involved in the proposal to establish a farm centre under control of the Council, and, by direction of the Lord President, the possibility of a revision of the Provisional Note on Administrative Arrangements was explored.

The outcome of these negotiations is described elsewhere in this Report. When it had been agreed that the Agricultural Research Council should have freedom to undertake experimental work at centres of its own, or elsewhere, the question about contagious abortion was again discussed with the Departments. Finally a scheme was adopted whereby work with large animals on fundamental problems not yet ready for investigation on a field scale, as well as researches with small animals, should be continued at existing Institutes, which would, where necessary, be strengthened for the purpose; but it was decided that the Agricultural Research Council should form a farm centre, which should act as a breeding station for experimental animals and might be suitable for undertaking investigations on specific problems in contagious abortion or other subjects, when such problems were remitted to it by the Agricultural Research Council.

Thus, just before the close of the two years under review, this troublesome question of the method to be adopted in extending experimental work on contagious abortion was settled, and the necessary changes in the agreed powers of the Council carried through. The way is now clear for details of the scheme of experiment to be formulated, and, it is hoped, a practicable method of controlling, or preventing, the disease to be discovered.

Work on contagious abortion aided by grants from the Agricultural Research Council and under the general direction of the Committee, with the co-operation of the Scottish Committee on Bovine Contagious Abortion and the Ministry of Health, was in progress or initiated at several centres during 1934 and 1935.

In the first place an eradication scheme prepared in 1933 was put into operation at seven centres, each of which supervises a segregation experiment in a number of herds. The segregation of Brucella-infected animals is determined by their reaction to an agglutination test carried out periodically on the whole herd. Meanwhile, the possibility of elaborating more accurate tests is being studied; these include an improvement in the technique of the complement fixation test and an intradermal test with a suitable brucellin. The scheme is voluntary and it was hoped that the owners of the herds would pay for the collection of the necessary blood samples. This proved, however, to be impracticable in certain cases and the Council had to meet a part of the cost. A number of herds in different parts of England and Scotland are under this scheme, which is on a large enough scale and over a sufficient period (five years) to provide a very useful guide to future policy.

As already indicated, a great deal of the research work on contagious abortion at several centres aided by grants from the Council's funds and at the Ministry's Laboratory at Weybridge is directed to the production of live or dead vaccines. At the Moredun Institute of the Animal Diseases Research Association near Edinburgh a study of the relative virulence of strains of *Brucella abortus* is in progress and similar work is carried on at Weybridge and in the Section of Preventive Medicine of the Royal Veterinary College, Camden Town. At Weybridge and elsewhere studies of the disease have been made also in other animals, such as pigs and horses, and on the preparation of different forms of abortin and the best way to apply it. Dr. A. W. Stableforth at the Royal Veterinary College undertakes the preparation of the suspensions for the agglutination tests and carries on studies of the cultural and other characters of the organism and of the prevalence of infection in cattle killed at the slaughter house, Islington. At Cambridge the viability of *Brucella abortus* in dejecta from infected animals and in the tissues of foetuses is under test.

Towards the cost of this work the Council made grants amounting in all to £1,665 during the two years. In Scotland considerable additional funds were raised locally; up to November, 1934, over £700 had been obtained from various bodies and individual donors and more had been promised. Amongst these were the £1,000 on a £ for £ basis spread over a period of years from the Highland and Agricultural Society and £200 per annum for three years from the Scottish Milk Marketing Board mentioned in the last Report. At the close of the period under review the Council learnt with pleasure of the decision of the English Milk Marketing Board to place at their disposal for work on contagious abortion a sum of £2,000 for each of the two years 1934 and 1935.

The Committee on Johne's Disease.

The Committee have continued to devote attention to ascertaining the best methods of diagnosing this troublesome disease. In a Report, dated the 28th September, 1935, the Committee gave an account of a second experiment with twelve cattle designed to test the value of different preparations of johnin as diagnostic agents. The animals tested included some affected with tuberculosis or with Johne's disease and some free from both diseases. Through the courtesy of the Medical Research Council the animals were accommodated at the Farm Laboratories at Mill Hill. Four kinds of johnin and two kinds of tuberculin were used, both in the undiluted and diluted states. The post-mortem examinations occupied a period of twelve months and the findings in the majority of cases accorded with predictions based on the results of the test. The value of johnin as a diagnostic agent was demonstrated and it was shown that the best results could be obtained with johnin prepared on synthetic media. The Committee state that much work remains to be done on the details of manufacture.

The Committee proposed that an extensive series of tests over a period of at least twelve months should next be undertaken with the synthetic products available on 100 cattle awaiting slaughter at the Islington abattoirs. The cattle would be tested with johnin and tuberculin and be examined thoroughly post-mortem by the staffs of the laboratories represented by the Veterinary members of the Committee. The Council accepted this proposal and set aside a sum of £250, to include savings on the second series of experiments at Mill Hill, for the purposes of the tests at Islington.

The Council further made a grant of £236 in aid of the cost of an investigation, to be undertaken by Dr. A. D. McEwen of the South-Eastern Agricultural College, Wye, over a period of two years beginning on the 1st January, 1935, on "Johne's disease" in sheep. The investigation is being made under the general co-ordination of the Council's Committee on Johne's Disease. It is not known how far the disease is, in fact, prevalent among sheep, and it is important to discover the relationship of the causal micro-organism in sheep to that found in cattle and to ascertain whether cattle can be infected by transmission of the strain of the bacillus found in sheep. Considerable difficulty has been found in cultivating the sheep strain of the bacillus artificially. The conditions in the Wye area are favourable to a study of these problems, as two years previously a heavy mortality due to "Johne's disease" had occurred in a flock of breeding ewes and the disease had not been entirely eradicated from the flock.

Mastitis.

In the Council's previous Report the decision to place no additional researches for the present on this disease elsewhere than at the Research Institute in Animal Pathology, Royal Veterinary College, was recorded. The staff of this Institute were undertaking intensive research on this disease, partly aided by grants from the Royal Agricultural Society of England. The Council have kept the position under review and in October, 1934, their Animal Diseases and Nutrition Committees considered a report by Professor F. C. Minett, Director of the Institute, on the work done in 1933-4. This report had been prepared for the Journal of the Royal Agricultural Society of England.

Professor Minett refers to the streptococcal or common form of mastitis and to the staphylococcal form, which, though not common, may be serious and even fatal. He records that staphylococci may also set up a mild form of inflammation, causing slight but continuous deterioration in the milk, without, perhaps, any obvious disturbance. Out of 200 cows in three herds under observation, 35 per cent. were thus infected. Much time was given at the Institute during the year to studying the powerful toxins and antitoxins associated with staphylococcal infections under certain conditions. It is hoped that the injection of formalinised toxin before calving may help in controlling gangrenous mastitis. Staphylococcus mastitis has also been found to be common in ewes after lambing.

A new bacteriological culture medium for diagnosing mastitis has been devised in Professor Minett's Institute. It has been shown that the method used in the cowshed of testing the reaction of milk with brom-cresol-purple papers, though useful, is not so accurate as a laboratory test and that in about 10 per cent. of cases the " cowshed " method is definitely misleading.

The Institute's records indicate the wide prevalence of streptococcus mastitis in cows. Out of the milk samples from 2,530 cows in 48 herds, 970 (38 per cent.) were infected in at least one quarter. The percentage varied in individual herds from 10 to 71 per cent.

The method of controlling the disease by milking infected cows last is being tested in seven herds, which at the beginning contained 550 cows. Cows are examined at intervals of about three months. One herd has been free from infection for nearly five years, another since July, 1932, while in a third some cows still harbour streptococci in small numbers and at irregular intervals, but without obvious effects, after three years.

A beginning has been made in testing the value of continental methods of infusing chemical substances into the udder, with promising results in early cases where " entozon " is used. The results in cows which have been heavily infected for some time are not, Professor Minett finds, so satisfactory.

In 1935 a scheme of research was instituted at the Hannah Dairy Research Institute by Mr. S. J. Edwards, previously a member of Professor Minett's Veterinary staff, under the general supervision of the Mastitis Committee of the Scottish Board of Research in Veterinary Science, of which Professor Minett, and Dr. Norman Wright, Director of the Hannah Institute are members, and Mr. Edwards is Secretary. For the first year funds in aid of the special costs of the scheme were provided from local sources. The object is to try out the preventive methods initiated by the Research Institute in Animal Pathology under practical conditions in five herds, and to improve the technique of testing. Efforts have been made during the summer to perfect seals for use in preventing summer mastitis. The extent of infection on high and low protein rations is being investigated in a selected herd, and samples of mixed milk from farms have been examined on behalf of the Scottish Milk Marketing Board.

The Committee on Swine Fever, Necrotic Enteritis and Similar Diseases of Pigs.

The Committee presented their first Interim Report on the 17th November, 1933. After making two surveys, one on Swine Fever and Necrotic Enteritis, and one on the Non-Specific Disorders of Young Pigs, the Committee decided that work on the first two subjects should be done at Weybridge, since Swine Fever is a notifiable disease.

They considered that research should aim at developing methods of differential diagnosis, exploring serological methods and finding a small animal technique, and a way of active immunization.

Swine Erysipelas is quite as destructive as Swine Fever, and work is needed on the biology of the causative organism and on methods of active immunization. This, the Committee proposed, should be carried on at the Animal Pathology Institute at Cambridge.

Heavy mortality falls on young pigs during the first six weeks of life from obscure causes. The Committee recommended that a survey be made of the causes of the deaths of young pigs over England and Scotland, and that a peripatetic Veterinarian be appointed on a temporary basis to carry out the survey.

A second Interim Report was made by the Committee on the 30th September, 1935. This stated that the three lines of research proposed in the first Report had been commenced, but for various reasons had not yet progressed far. The survey of the obscure disorders of young pigs had been arranged by the Ministry of Agriculture on receiving the Council's advice, and was entrusted to Mr. N. H. Brooksbank, who was seconded from the Ministry's inspectorate for the purpose from the 1st January, 1935; this survey has proceeded actively. In regard to Swine Erysipelas, a grant of £400 from the Council's funds was made in 1934 to the Institute of Animal Pathology, Cambridge, for the salary of a whole-time research assistant to be engaged primarily on the investigation of vaccines intended for immunizing against the disease. It was subsequently decided to employ Mr. G. J. G. Halford, who was already on the staff of the Institute, for this work and to transfer the £400 to cover the expenses of the investigation for one year from the 1st April, 1935. In fact it has been possible to make but little progress with the investigation, as Mr. Halford has left the Institute's staff.

In May, 1935, the Council received a donation of £500 from Imperial Chemical Industries, Ltd., for a special investigation into the use of disinfectants against the swine fever virus. This sum was made available for work on chloros and other disinfectants to be carried out at the Ministry's Veterinary Laboratory, Weybridge, under the general supervision of the Committee on Swine Fever, etc. It is being used to pay the salary of a research assistant and other expenses over a period of six months; Dr. G. Slavin was appointed to carry out the work from the 1st October, 1935.

The Committee on Helminths of Economic Importance (Animals Section).

The Committee on Helminths did not present a Report during the period under review, but some account of their activities may be given. As recorded in the Council's last Report, the Committee at its first meeting had agreed upon a list of the helminths which are of chief importance in their effect upon the health of livestock and as to the importance of discovering which of the nematodes is the most common cause of parasitic gastritis. The Committee considered that sufficient was known of the life histories of the two species of liver fluke to form a scientific basis for control measures. Generally, the Committee were of opinion that one of the chief aims of further research should be to find drugs which will kill helminths causing infection in animals, since the practice of moving animals on to clean land at intervals (rotational or " progressional " grazing) can only be followed on large farms, and to gain further knowledge of the physiology of nematodes in relation to the action of helminthicides. Further knowledge seemed also to be required on the action of drugs in the ruminant stomach and on the sensitivity of the infective larvae of nematodes to changes in their natural surroundings. It has been observed that animals on two apparently similar pastures may be infected in different degree.

At their second meeting the Committee conferred with the Chairman of the Council's Animal Nutrition Committee and with some of the members of the Animal Diseases and Nutrition Committees. Recent work on nematode infestation of sheep, which seems to be of greater importance than had been suspected, at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, the Rowett Research Institute, Aberdeen, and at Winches Farm (Institute of Agricultural Parasitology) was discussed. The Ministry's experiments and those at Aberdeen pointed to the success of a system of progressional grazing, that is to say of moving sheep on to uncontaminated land at intervals of from a week to ten days. In the Aberdeen experiments infection with *Haemonchus contortus* was less by 99 per cent. in the sheep which were moved to clean plots than in the control groups, and infection with *Ostertagia circumcincta* was less by 80 per cent. At Winches Farm the object was to study the effect of an intensive system of grassland management, in the course of which stock is grazed over a series of plots, which are heavily manured, in rotation, upon the extent of worm infestation. It was found that during the summer the animals under experiment suffered little harm, but that infestation increased in the autumn and all the animals died during the winter. The workers at the Ministry's Laboratory and at Aberdeen found that certain factors, possibly nutritional, have an influence on the egg producing capacity of the female worm and on the degree of resistance to infection of the sheep. Infection is also less in a dry summer. It must be remembered, however, that the experiments recorded have been done on very small numbers of animals. The time may not yet be ripe for large field experiments, but possibly more rapid progress could be made by using such laboratory animals as rabbits, which are infected with some of the same parasites as sheep. It was reported to the Committee that very promising results had been obtained by Dr. A. D. McEwen of Wye in large scale field experiments by using nicotine sulphate and copper sulphate as a helminthicide.

At their third meeting the Committee reviewed the work done on progressional and rotational grazing, and the bearing upon these methods of control of the information gained as to the time taken by the larvae of sheep parasities to reach the infective stage, as to the means of spread of infection under natural conditions, and as to the effect of drought on helminth eggs. They reached the conclusion that while adequate nutrition and progressional grazing were of importance in controlling sheep helminths, it was very desirable to undertake further research on simple helminthicides. Their use might prove to be more easily applied and economical. The Council agreed as to the need for investigations such as the Committee proposed, and reference has already been made in the section referring to the Institute of Agricultural Parasitology (page 74) to the special grant made by the Council to the Institute for this purpose. It was noted that studies on helminthicides could also be undertaken in the Ministry's Laboratory at Weybridge, and that the facilities for a close examination of the connection between nutrition and the worm burden in sheep were specially favourable at the Rowett Research Institute. In view of the importance of the application of modern statistical methods to helminth investigations Dr. R. A. Fisher was invited by the Council to become a member of the Committee on Helminths.

At the fourth meeting of the Committee, held immediately after the end of the period under review, Professor Leiper described the programme of work to be undertaken with the assistance of the Council's grant on anthelmintics. The first aim was to find a chemical substance which could be used to keep in check the Trichostrongylidae. It was reported that, at Weybridge, Dr. H. H. Green of the Ministry's staff was investigating the effect of intravenous injections with various chemicals on a species of *Trichostrongylus* in rabbits, and was considering the probable effect of nicotine sulphate on the trichostrongyles of sheep. Experiments under Dr. Robertson at Aberdeen indicated that dosing lambs with carbon tetrachloride and copper sulphate resulted in an increase in their weight when compared with that of the control animals. Similar results with copper sulphate had been obtained in Roxburghshire.

An account was given of other researches in progress at Winches Farm, in Hertfordshire, the field station of the Institute of Agricultural Parasitology, and of work which Mr. E. L. Taylor was undertaking at Weybridge on low-grade infection in lambs associated with loss of weight, on the effects of housing lambs at night on the worm burden, and on the migratory habits of infective larvae on different herbage plants.

Dr. A. H. H. Fraser of the Rowett Research Institute informed the Committee that a detailed analysis of the worms from 70 lambs was being made and that the effect of salting pastures was being investigated. It was proposed to continue the worm counts in 1935-36 and to examine the degree of worm-infestation in lambs living under different nutritional conditions. The Committee learned from their Secretary, Dr. D. O. Morgan, that he had been carrying on an extensive survey of the worms infesting poultry in Scotland, using material supplied through the Royal (Dick) Veterinary College. Controlled experiments with the chemicals usually recommended for treating heavily infected poultry runs had shown them to be quite ineffective against the eggs of nematodes. The experiments were to be repeated on pens placed at Dr. Morgan's disposal by the Edinburgh and East of Scotland College of Agriculture.

The grant approved for the second academic year, 1934-35, in which investigations on the intestinal parasites of sheep, carried on in collaboration with the Natural History Department of Aberdeen University, have been aided by the Council at the Rowett Research Institute, was a sum not exceeding £230, and it was to be used to meet the salary of a worker and expenses in connection with the programme of work which has been described above. The survey of the species of worms affecting sheep in Scotland was to be published, with the detailed analyses of the stomachs and intestines of ewes and sheep from Garrochoran, Argyllshire, the Institute's hill farm. These showed no differences in the type or number of worms which could be correlated with the feeding of minerals. On the Duthie Experimental Stock Farm, attached to the Rowett Institute, a study of the worm burden of fat lambs of known history was in progress and it was found that a burden of 3,000 or more worms did not prevent a lamb reaching butcher fatness in four months.

Sheep Blow Flies.

Some account was given in the Council's last Report of the work which Dr. R. P. Hobson with the aid of grants from the Council's funds was doing in the Department of Entomology at the London School of Hygiene and Tropical Medicine, under Professor P. A. Buxton's direction, on the growth of the larvae of the sheep blow fly (*Lucilia sericata*) on blood and serum and on the part played by associated bacteria in promoting growth. Dr. Hobson had also been studying the response of the larvae to different oils, when they were fed on a diet free from fat. It was explained that a stage had been reached when it was desirable to apply the knowledge gained to experiments with sheep, and that a further grant at the rate of £145 for a period of six months had been made to cover the period from the 1st October, 1933, to the date of Dr. Hobson's transfer to the University College of North Wales, Bangor, where Professor R. G. White was arranging for him to have the necessary facilities for field work in an area in which sheep farming is predominant, and Dr. Maldwyn Davies, the Adviser in Agricultural Zoology, had been studying the blow fly problem for some years. The main lines of the investigations at Bangor were to be an examination of the conditions favouring "strike," a further study of the nutrition of young larvae in relation to serous and skin exudations, bacteria and wool impurities, and an attempt to find out what attracts the fly to lay eggs on the sheep. In aid of this programme the Council made a non-recurrent grant of £100 for apparatus and a maintenance grant of £254 for the seven months from the 1st March to the 30th September, 1934, being at the rate of £435 per annum, to meet Dr. Hobson's salary and the expenses of his research. In reporting upon his work during this period, partly done in collaboration with Dr. Maldwyn Davies, Dr. Hobson records that it was found that various putrefying substances, of which larval excreta were the most effective, attracted the blow fly *Lucilia sericata* to lay eggs regularly on sheep kept in a small paddock, but only on a live sheep. Other carrion flies were not attracted. It was further found that very high humidities at the base of the wool and warmth were conditions necessary to the development of the eggs and the growth of the larvae of *Lucilia*.

For a continuance of these researches during the academic year 1934-35 the Council made a grant not exceeding £525, which provided for an increase in Dr. Hobson's salary, for new expenditure on the maintenance of a small greenhouse placed at the disposal of the investigators for the breeding of flies during the winter, and for the employment during the summer of an additional junior laboratory attendant. Investigations were planned on the conditions causing high humidities at the base of the sheep's wool, on the action of certain products in attracting the flies, on the efficiency of repellants and larvicides, and on the factors necessary for successful infection of sheep in the field.

Application was made by Professor James Ritchie, head of the Zoology Department, Marischal College, Aberdeen, for a grant of £75 to enable investigations on sheep blow flies to be carried on for a further year, beginning on the 1st June, 1934, jointly by the staff of the Natural History Department and the staff of the Rowett Research Institute. The Council agreed to make the grant on condition that collaboration was maintained with Mr. A. C. Evans of the London School of Hygiene and Tropical Medicine and with Dr. R. P. Hobson, whose work at Bangor has just been described. Both workers were being assisted by the Council.

During the summer of 1933 an area surrounding Aberdeen was surveyed with the object of discovering what species were responsible for " strike ". Mr. F. N. Ratcliffe, who had experience in Australia of sheep blow fly investigations, was responsible for the field work and also for the laboratory observations mentioned later. Shepherds widely hold the belief that the blue-bottle (*Calliphora erythrocephala*) is responsible for a considerable number of cases, but the evidence seems to show that the so-called blue-bottles are really fully fed specimens of *Lucilia sericata,* though the blue-bottle has been known to strike sheep. Ewes were found to be the victims during the early summer and they were usually struck above the root of the tail; lambs were struck after the ewes had been clipped. Round Aberdeen flies were sufficiently abundant to have struck all the sheep, but certain sheep seemed to have a peculiar attraction for them. Once one or more flies have struck, they produce conditions on the sheep which attract a large number of flies. While it seems to be beyond question that a dirty fleece, or a sheep which is sweating badly or has a damaged skin, will attract flies, it is not understood why a few sheep in a clean and healthy flock will be struck. The fleece lying closest to the skin appears to be the most favoured part for egg laying.

A short trial was made in 1933 of a dressing for affected sheep recommended by the South African Department of Agriculture. A proper trial was proposed for 1934. From August onwards breeding experiments were made in the laboratory with a small number of blow flies. An average of 1,683 eggs per female was laid, each female laying on the average nine batches at average intervals of from two to three days. This experiment was carried out under the most favourable conditions as regards constant warm temperature and an abundance of food, which would not be found in the field. It is thought that under natural conditions a single female would lay a batch of well under 100 eggs. The time between laying and hatching in the course of these experiments was under 24 hours at a temperature of 27° C., about 24 hours at a temperature of 20° C. and at room temperature about 36 hours. Temperature plays a large part in determining rate of growth, length of feeding time of the larvae, the dormant period which precedes pupation, and the length of the pupal period.

A questionnaire was circulated to some 700 farmers in other parts of Scotland, to which replies were arriving at the date of the report, and experiments were made by Dr. Guy Morison of the North of Scotland College of Agriculture, with traps, which were a modified form of the "West Australian" trap. In seven traps over a period of 165 days from the 9th May to the 20th October, 1933, a total number of 2,040 females of *L. sericata* and 171 males were caught. Of *L. caesar* 21,292 females and 1,819 males were caught. No direct correlation was found between the amount of rainfall, or between other meteorological factors, and the number of flies caught, though it must be noted that the period between visits to the traps was as long as four days.

During the period that the traps were operated 86 ewes and 277 lambs were observed by the shepherd of the Rowett Research Institute to have been struck. The rise and fall in the numbers struck seemed to correspond to the rise and fall in the numbers of flies caught in the traps.

In 1934-35 it was intended to continue breeding experiments in the laboratory, to collect catches daily from a limited number of traps, to observe by using suitable baits the preference of blow flies and blue-bottles for carrion in different stages of decomposition, to undertake the investigation of strike in the field and make controlled trials of special dressings.

The Committee on Fowl Paralysis and Allied Diseases and on Coccidiosis.

In the First (Interim) Report of this Committee recommendations were made for carrying out carefully controlled breeding experiments for the purpose of testing the view that susceptibility to fowl paralysis is inherent in certain strains of poultry. Grants were also recommended in order to aid work at Manchester University on the histology of the disease and at the Molteno Institute at Cambridge on its cause, diagnosis and relation with nutrition. These recommendations were accepted and grants were made in 1934 of £188 to Cambridge and £75 to Manchester. The main breeding experiments were intended to be carried out at the Ministry's Veterinary Laboratory at Weybridge, but there have been serious delays in securing the necessary accommodation there and it was not found possible to make a start within the period covered by this Report.

Further grants of £150 to Cambridge and £100 to Manchester were made for the year commencing the 1st October, 1934, for the continuation and extension of the work on this disease. A breeding experiment was also commenced on a relatively small scale in the spring of 1934 at the Wellcome Physiological Research Laboratories at Beckenham in Kent; the cost of this was defrayed by the Scientific Poultry Breeders' Association. At the Institute of Animal Pathology at Cambridge a survey of the incidence of fowl paralysis in the surrounding district, where it seems to have first appeared in 1932, was made and transmission experiments were begun.

The Committee submitted a Second (Interim) Report in September, 1935. This stated that a critical review of the literature on fowl paralysis had been prepared by Major T. Dalling of the

Wellcome Research Laboratories and that this review would be published. The term "fowl paralysis" is a loose one; paralysis is not necessarily a prominent feature in all cases, and may occur in other fowl affections. There is still a difference of opinion as to whether the condition should be termed "neuro-lymphomatosis" and restricted to cases in which the nerve structures are infiltrated with lymphatic cells, or "lymphomatosis" and widened to cover similar infiltrations in many other organs and tissues.

Routine post-mortem examinations at various centres in Great Britain during the past two years have shown that lymphomatosis is a comparatively common condition, affecting from 5 to 20 per cent. of the birds presented for routine autopsy. It is not common in birds over a year old. Ovarian tumours are a frequent concomitant, but there is not the same agreement that the type of blindness due to affections of the iris, and known as "grey" or "pearly" eyes, observed in fowls is associated with the disease. This question is under study at Beckenham and the Molteno Institute. The attempts to transmit the disease carried out at Manchester by Professor S. L. Baker, at the Cambridge Institute of Animal Pathology by Mr. R. E. Glover and at Beckenham have given no clear support to the view that fowl paralysis spreads by simple direct contact. Inoculations with fresh diseased tissues gave some suggestive, but not conclusive results. Thus, at the Molteno Institute, Dr. H. P. Bayon found that only eight out of 414 chicks of various ages up to three months showed nerve lesions six months after having been inoculated with tissue suspensions from birds with lymphomatosis; most of the chicks, however, showed lymphoidal infiltrations of other tissues or organs. In other transmission experiments done at Manchester, where intracerebral inoculation has been tried, and at Beckenham, it has been found invariably that though typical cases occurred in the inoculated birds, some cases also appeared in those that were not inoculated or that were inoculated with material from normal healthy birds. There is some evidence that the strain of birds used affects the inoculation results. Certain strains classed as "susceptible", that is to say coming from flocks in which fowl paralysis was known to be present to a considerable extent, seemed to give the most significant results in these tests.

The breeding work carried out under Major Dalling's supervision at the Wellcome Research Laboratories has been extended and has given interesting results. Groups of pullets were mated with cockerels from different families. The general results are that certain birds or groups of birds produce affected progeny to a greater degree than do others; the fact that a pullet ultimately develops fowl paralysis does not necessarily mean, however, that her progeny will also become affected. Further experiments on these lines are in progress and must continue for some time, as it is necessary that all the progeny should be bred. In the survey carried out by Mr. F. Blakemore of the Institute of Animal Pathology, Cambridge, 15 out of 30 of the flocks in which the distribution of the disease was noted had the attacks restricted to fowls from purchased eggs or chicks, in four others the affected birds were the progeny of an infected flock; in two they were the progeny of cocks which developed fowl paralysis after mating; in six they were the progeny of purchased cocks and hens which remained healthy and in three (two not reliable) no fresh stock had been introduced during the previous four years.

The Committee supported a proposal that a survey of the incidence of fowl paralysis in Scotland should be undertaken by the Royal (Dick) Veterinary College, Edinburgh. It is recommended that this should be on intensive lines in certain areas.

In regard to the diagnosis of the disease, the Committee examined claims that it is possible by direct microscopical examination of blood smears to tell whether the birds are affected, especially in the early stages of attack. The Committee were unable to satisfy themselves that this was a satisfactory method of diagnosis.

The relationship of fowl paralysis to some forms of avitaminosis was considered. While there was some evidence suggesting that deficiency of vitamin A or one of the fractions into which vitamin B is now split may sometimes be associated with the occurrence of fowl paralysis, and that the forcible feeding of obviously affected birds with green food was followed by an improvement in the clinical condition, the Committee felt that more evidence was necessary before any relationship could be shown to exist. From the evidence submitted the Committee do not consider that coccidia or other intestinal parasites play an initial part in the causation of fowl paralysis. Dr. Bayon is carrying out further studies at the Molteno Institute of the histological differences between neuro-lymphomatosis and the type of paralysis found in coccidiosis.

The Committee state that they have obtained no evidence which would indicate the true cause of fowl paralysis.

A disturbing feature of this obscure disease is the indication that it is one of the factors responsible for the alarmingly high mortality rate of birds at laying trials. During a few years this rate rose from 12 to 34 per cent. and it is understood that a high proportion of the deaths were due to ovarian tumours.

The work so far carried out indicates that there is much confusion regarding the diseases of the blood-forming tissues in fowls and their relation to fowl paralysis. Work on some of these is in progress at the Molteno Institute, where evidence has been obtained that tumours of the lymphoma type can be transmitted by inoculation, though this was not accompanied by the nerve infiltration described as characteristic of neuro-lymphomatosis. Other diseases under study include a transmissible " erythroleucosis ", characterised by greatly enlarged spleens and livers, but without infiltration of the nerves.

Owing to the extension of the work on fowl paralysis the Committee were not able to give much attention to coccidiosis. Experimental work on this disease was confined to the Wellcome Physiological Research Laboratories and has been concerned with (*a*) the possibilities of rearing stock free from coccidia; (*b*) experimental transmission of the disease with pure strains of coccidia; (*c*) various methods of prevention and treatment, e.g., with iodine, hydrochloric acid, sour milk; (*d*) immunity.

It has been demonstrated that it is possible, though not easy, to keep fowls free from coccidia for months if they are obtained as healthy day-old chicks. A few experiments indicate that it may be possible to set up an immunity against a particular species of the parasite; further work to extend this to several species is now in progress. Some of the treatments advised for the prevention of the disease have been found unsatisfactory.

MISCELLANEOUS RESEARCHES.

" Blackhead " in Turkeys.—Experimental work on the value of neosalvarsan and other arsenical preparations for the treatment of infectious entero-hepatitis (" blackhead ") in turkeys was aided by a grant from the Council's funds to the Harper Adams Agricultural College of £100 for the year beginning on the 1st June, 1933. A further £50 was granted for the financial year 1935-36 to extend the work to the testing of some non-arsenical preparations. This became advisable when it was found that a single treatment with an arsenical compound was of little value unless the birds could be removed to clean ground; if no clean ground is available it is necessary to repeat the injections at weekly intervals for a considerable time. There

is then a possibility of cumulative effects of the arsenic in the liver.

The substances selected for detailed testing as having been reported to have given good results in practice were sodium hypochlorite and carbon tetrachloride, both of which were said to be suitable for oral administration, cheap, and more desirable than the arsenicals. The experiments are being carried out by Mr. K. D. Downham, Veterinary Adviser to the College, with the co-operation of the staff of the Ministry's Veterinary Laboratory at Weybridge.

Disabling Disorders in Horses.—For some years Professor W. M. Mitchell of the Royal (Dick) Veterinary College, Edinburgh, has been carrying out an investigation into osteo-arthritis and allied conditions in horses, and he has reached the conclusion that many of the localized disabling diseases of horses are manifestations of a generalized disease. Among the disorders that are under consideration in this connection are shivering, stringhalt, roaring, ringbone, bone spavin, etc. Professor Mitchell considers that the multiple bone and joint lesions found in severe cases of these disorders are associated with polyneuritis; he adopts the view, previously put forward by the late Sir Arnold Theiler and others in regard to some of them, that the whole group is due to dietary deficiency.

The Scottish Board of Research in Veterinary Science, after a careful examination of the material collected by Professor Mitchell and detailed consideration of the work already done and contemplated, urged that it should be continued, as it seemed to have very important practical and scientific bearings. The Board supported an application to the Agricultural Research Council from the Royal (Dick) College for a grant to enable Professor Mitchell to continue his anatomical and pathological studies and to assist Professor R. G. Linton of the College to carry out as a correlated piece of research a study of the mineral supply in the dietary and estimations of the liver reserves of vitamin A. At a later stage it was proposed to commence an experimental study of these disorders, Shetland ponies being used for this work; in a natural out-of-door life in the Orkneys and Shetlands these ponies are singularly free from these troubles, but they develop them under artificial working conditions.

In July, 1935, the Council made a grant from the funds at their disposal of £332 for a year from the 1st October, 1935, to enable this work to be developed at the Royal (Dick) College by Professors Mitchell and Linton.

Bureau of Animal Population, Oxford.—The interesting work of the Bureau of Animal Population, under the direction of Mr. C. Elton of the Department of Zoology and Comparative Anatomy at Oxford, was briefly described in the Council's previous Report.

The grant of £150 made by the Council in 1933 was used to pay part of the salary of Mr. A. D. Middleton for field work on periodic fluctuations in the numbers of field voles and other wild mammals and for laboratory expenses. Further grants of £100 from the 1st February to the 30th September, 1934, and £150 from the 1st October, 1934, to the 30th September, 1935, were made by the Council for the continuation of the field survey; this is based on an intelligence service by many hundred voluntary observers, who report to Mr. Middleton the fluctuations and epidemics among voles, squirrels, moles, hares, rabbits and other species. Several aspects of this work received support from other public bodies, such as the Forestry Commission, and from private sources. The Council's grants were expressly made in order to give time for a careful consideration of the future status and financing of the Bureau of Animal Population.

Subsequently, the future of the Bureau was taken into consideration by the Agricultural Research Council's Committees on Animal Diseases and Animal Nutrition at a meeting on the 30th October, 1934, which was attended by Professor E. S. Goodrich, Linacre Professor of Zoology and Comparative Anatomy at Oxford, and by Mr. Elton. It was ascertained that while the University had provided temporary housing and certain overhead services, all the financial resources of the Bureau came from *ad hoc* grants made by independent bodies.

The Council expressed to the University of Oxford their hope that the University would be able to secure funds for the endowment of the Bureau on a permanent basis.

In 1935 further developments occurred. Arrangements were made with the newly appointed Professor of Pathology, Professor H. Florey, for co-operation in the study of the causes of certain epidemic diseases of wild mammals as a factor in the periodic fluctuations in their numbers. Furthermore, the University expressed their desire, if the success of the Bureau on an experimental basis continued, to put it on a more permanent basis. The Council made in July, 1935, a grant of £180 in aid of the general work of the Bureau for the year commencing the 1st October, 1935, and a grant not exceeding £500 towards the capital cost of an isolation laboratory.

The Bureau is developing with the central aim in view of elucidating the factors determining fluctuations in the density of wild animals. The solution of these population problems requires a precise knowledge of the reproductive potentialities of the population, of animal behaviour and ecology, of the factors causing mortality, and of actual densities as studied by special census techniques. Each of these phases has its economic aspect; the subject is of increasing biological interest and has principles of its own, which the Bureau is making progress towards discovering. Of interest to agriculture is the light that may be thrown on the epidemiology of certain animal diseases and on the causes of periodic increases of rodent pests. An important aspect is the part played by climate and weather in affecting animal numbers; recent studies on the three-four-year fluctuations in Scottish field-mice have brought to light the existence of an important three-four year fluctuation in North Atlantic weather, hitherto unsuspected.

VIII. DAIRY RESEARCH

As explained in the first Report, there are two Institutes for Dairy Research—the National Institute for Research in Dairying, connected with Reading University, and the Hannah Institute, at Kirkhill, Ayrshire. The West of Scotland Agricultural College at Auchincruive, very near the Hannah Institute, has also a Dairy Research Department. These three institutions were visited by a Sub-Committee of the Agricultural Research Council in December, 1934 and January, 1935.

The work of the National Institute at Shinfield, near Reading, has been seriously hampered, both physically and financially, by an unfortunate outbreak of contagious abortion in the dairy herd. The large amount of advisory work, commented on in the first Report, continues to occupy much time of the staff which might otherwise be given to research. The work undoubtedly serves to maintain contact with practical dairying, and, in moderation, is useful. At Shinfield it had perhaps grown too burdensome, but it has now proved possible, from the fees earned, to provide a well-qualified technical assistant to help the scientific staff with advisory work.

The Institute continues its work for the Ministry of Agriculture and Fisheries in testing dairy machinery, such as pasteurizing plants, milking machines, sterilizers, etc.

The buildings as a whole are inadequate for the work going on, though the library is now well housed in the Stenhouse Williams' Memorial. There is need for continual advice from a qualified statistician for planning experiments and evaluating results.

Dr. H. D. Kay, the Director, is himself specially interested in the physiological problems of milk secretion, about which surprisingly little is known. The Physiology Department has lost the services of Mr. G. L. Peskett, and, at the time of the Sub-Committee's visit, was staffed by Dr. S. J. Folley and Dr. W. R. Graham. Dr. Kay wishes to develop this side of the work as soon as funds allow. Dr. Folley was studying the physiology and biochemistry of mammary gland tissue, more particularly the phosphatase content. Dr. Graham was tracing the differences in composition of the blood entering and leaving the udder, with special reference to fatty acids, phosphate, sugar and lipin phosphorus.

The Dairy Husbandry Department under Mr. J. Mackintosh was continuing the work of the earlier years and testing the effect of external temperature and other factors on the non-fatty solid contents of milk. No appreciable improvement in milk of low content has been secured by varying the conditions, though there are some indications of a climatic effect. The experimental dairy, under Miss D. V. Dearden, was examining the influence of oxygen tension on the mould growth and rate of ripening of Stilton cheese. The farm and the dairy provide material on which much of the work of the laboratory departments is based.

Captain J. Golding is in charge of the Chemistry Department, in which Dr. W. L. Davies and Mr. Trevor Jones work. They are engaged on the study of the faults of milk, butter and cheese, the devising of standard methods of analysis and of biological measurements of vitamins, the nature of vitamin D in butter and the examination of enzymes in milk. The " beet taint " of milk has been traced to trimethylamine derivatives, which are found in cows fed on beet products. Work on this problem was supported for some time by grants from the Sugar Beet Research and Education Committee and was later assisted directly by the Council, who have approved a grant of £320 for the continuance of the investigations during the financial year 1935-36. " Fishiness " in butter has been traced to autoxidation of lecithin, a process favoured by metallic contamination.

Dr. S. K. Kon has completed the survey begun in 1931 of the seasonal variation of vitamins in milk. Summer milk may contain three times as much fat-soluble vitamins as winter milk, but the amount of vitamin B does not seem to change.

In the Bacteriology Department Dr. A. T. R. Mattick is assisted by Dr. J. G. Davis, Miss E. R. Hiscox and Miss P. M. F. Shattock. They were working chiefly on the factors concerned in the ripening of cheese and on lactic acid bacteria. Results are appearing—for instance, the optimum hydrogen-ion concentration for ripening has been defined, and the effect of fermentable acids and the effect of calcium in controlling the clotting of milk have been established.

Lieut.-Col. E. C. G. Maddock's work on the viability of the tubercle bacillus in pastures, which has been assisted since December, 1932, by grants from the Council's research funds, was being continued at the time of the visit. Fuller reference is made to this work on p. 78.

The Sub-Committee reported that they were favourably impressed with the work of the Institute as a whole.

When the Sub-Committee visited the Hannah Institute, Dr. N. C. Wright, the Director, and Mr. S. Morris were carrying out experiments on the biological feeding value of spring and autumn grass, first when it was fresh, and latterly when it was dried in a drier (described in the Chapter on Agricultural Engineering), lent to the Institute by the Agricultural Research Council. Dr. Wright finds that it is safe to leave 10 to 15 per cent. of moisture in dried grass. The yield of grass from heavily manured plots was much in excess of that from the controls during the first two years, but the advantage was less in the third year.

Dr. J. H. Blackwood was continuing her studies of the precursors of the milk constituents in the blood. The work on the possible relation between lipins and milk fat had been finished and attention was being directed to the various fat fractions of the blood.

Dr. G. R. Howat was studying the factors which affect the solubility of commercial milk products, such, for instance, as the influence of heat on the individual constituents of milk, especially casein. Miss I. W. Mitchell, employed under a direct grant from the Scottish Milk Marketing Board, was making a bacteriological study of canned milk and cream, and the defects to which they are subject.

In April, 1934, Mr. S. J. Edwards, from the Royal Veterinary College, London, was appointed as Veterinary research worker on the staff, and has been engaged almost wholly on an experimental segregation scheme for the control of bovine contagious abortion. The Hannah Institute is situated in an important dairy farming area, but the relation of this work to that going on in places such as Moredun and the Royal (Dick) College, specially charged with the study of animal diseases, has been under the consideration of the Agricultural Research Council. The Sub-Committee speak highly of the ability and enthusiasm of the staff of the Institute.

The West of Scotland Agricultural College is almost adjacent to the Hannah Institute, and co-operation between the Dairy Research Department in the College and the Institute is desirable. In that Department, Professor R. H. Leitch was, the Sub-Committee found, continuing his studies on milk and dairy products, dealing with a variety of problems of practical importance, especially the biological processes of cheese production, such as the effect of using bacterial cultures of *B. acidophilus* as a " starter ". He emphasised the importance of good quality in the milk used for cheese-making, and considers that one of the main difficulties is the frequent presence of mastitis infection in the milk.

Dr. McCandlish had finished his comparison of raw and pasteurised milk for the rearing of calves. He finds that raw milk is the better. It will be interesting to see if this result stands critical consideration and further experiment.

During the period under review, the dairy industry has been profoundly affected by the institution of the Milk Marketing Boards and the measures that these Boards have adopted. The Agricultural Research Council and the Ministry of Agriculture and Fisheries have jointly advised the English Milk Marketing Board in regard to applications for grants for research submitted to the Board. On the advice of the Council and the Ministry, grants were made by the Milk Marketing Board to the National Institute for Research in Dairying for investigations on the compositional quality of milk, the feeding of dairy cows and the ripening of cheese, and to the London School of Hygiene and Tropical Medicine for an investigation into a rapid method of estimating the cleanliness of milk. The Scottish Milk Marketing Board were also advised by the Council, after consultation with the Department of Agriculture for Scotland, upon the allocation of funds set aside by the Board for research purposes. In accordance with the Council's advice, grants were made by the Board to the Hannah Dairy Research Institute for the examination of tinned products made at the Board's creameries and the investigation of specific defects found in such products, and to the Institute of Animal Genetics, University of Edinburgh, in aid of Mr. Buchanan Smith's research work on the hereditary qualities of dairy cattle.

The Council have requested their Dairying Committee to prepare a general survey of dairying research in progress in Great Britain. As stated above, a Sub-Committee of the Council has visited the Institutes engaged in dairying research and the Dairying Committee are now completing their enquiries in preparation for their report to the Council.

IX.—AGRICULTURAL ENGINEERING

The Institute for Research in Agricultural Engineering, Oxford, has continued its survey of mechanized farms, and issued a report in the form of notes.* It is pointed out that the success of cereal growing depends chiefly on the organization of labour and implements at harvest time. An increase in the cereal acreage up to the limit which can be handled in a normal season leads to increased efficiency, but beyond this a greater area will mean duplication of labour and machinery. It is then better to add some enterprise which, in its busy season, coincides with a slack period in cereal growing.

A Sub-Committee of the Agricultural Research Council and a Committee of the Development Commissioners have visited the Oxford Institute during the period under review, and consulted with the Director and Staff on the present and future work of the Institute.

As regards the design of farm implements, Dr. B. A. Keen of Rothamsted is in favour of high speed cultivating machinery, which disintegrates the furrow slices more. Comparisons of the action of roto-tillers with gyro-tillers and with ploughs have been continued.

At Rothamsted, too, an investigation is going on to determine the relative cost of electric motors and tractors in driving barn machinery. The variation in tariff charges for electric current puts a real obstacle in the way of predicting the cost of electric power.

At Cambridge studies of the drainage of heavy clay have been made by Mr. H. H. Nicholson, who shows that, at depths beyond the reach of cultivation or root penetration, the clay is impervious to water. Mole drains below cultivation level therefore depend on the slits remaining open.

As stated in the last Report, a Conference on the drying of grass and other fodder crops was held on the 14th March, 1933. The result was the formation of an expert Committee, under the Chairmanship of Sir William Dampier, to consider the Preservation of Grass and other Fodder Crops. The Committee divided themselves into two Sub-Committees, one, the Process Sub-Committee to deal with engineering problems, and another, a Sub-Committee on nutrition and grass land management. The

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* (1) Notes on the technique of mechanised farming, also Farm and Machine II, p. 73.
(2) Journal of Inst. of Automobile Engineers, 1934, p. 179.

Committee and Sub-Committees have held six meetings, and early in November, 1935, published a Report.*

The Committee gave reasons for believing that the artificial drying of grass at the usual hay stage is not an economic proposition: the nutritive value is not high enough to cover the cost. But if the grass be cut at a height of 5 to 8 inches at the most leafy stage, the nutritive value of the solid matter is equal to that of concentrates, even without taking into account vitamins, etc., and the money value is consequently so much higher that the margin for artificial drying becomes adequate.

Inlet gases at 250°C. from a furnace do no harm to the grass while moist, if the drying process is finished at a cooler temperature. Grass so treated is found to retain practically all the valuable properties of fresh young grass.

Even ignoring the very real value of vitamins, etc., the starch equivalent and protein contents of such dried grass were worth about £5 15s. per ton on the prices of concentrates in 1935. The cost of cutting, collecting and carting was estimated at £2 4s. 1d., which left a margin of 71s. to cover the cost of drying and other processes. The Committee were doubtful if factory-scale plant could work within this margin, owing to difficulties such as organizing a steady supply of raw material and others, but a farm-scale plant might be worked at times when the pressure on labour is not great, and might use surplus grass otherwise wasted.

The Committee therefore made a survey of farm-scale driers already available. All depend on blowing or drawing the gases from some form of furnace through a mat of grass, placed either on perforated trays or endless bands, though some large-scale driers are of rotary construction. The number of farm-scale driers actually on the market is very small, and the prices for the smallest sizes, ranging from £400 to £500, are high for farmers' resources. But the possibility of the process has been clearly demonstrated, and doubtless the capital cost will fall as manufacturers gain experience. The Committee hold that, "if the different problems of growing, cutting, collecting, drying and storing can be solved, something not far short of a revolution would be caused in grassland farming."

Early in 1935 the Council placed a sum of £1,000 at the disposal of their Committee on the Preservation of Grass and other Fodder Crops in order that tests might be carried out under controlled conditions on the cutting and drying of grass and to aid in testing the nutritive value of the dried grass.

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* A.R.C. Report Series No. 1. H.M. Stationery Office. Price 1s.

With this a Ransomes Grass Drier and Wilder " Cutlift " grass combine and Hornsby mower and trailer were purchased at a specially reduced rate offered by the makers, and placed on loan at the Hannah Dairy Research Institute. A grant of £484 was also made to the Institute for the installation and fittings of the drier and baler. It was decided that a thorough test of the mechanical and thermal efficiency of the drier should be carried out, and for this purpose the Council and the Institute were fortunate enough to enlist the co-operation of Professor A. L. Mellanby and Dr. A. W. Scott of the Department of Civil and Mechanical Engineering of the Royal Technical College, Glasgow. Operations were begun at the Hannah Institute in May, 1935, and continued throughout the season. A full analysis of the results to cover a second season's testing must be reserved for a future Report, but it is already clear that they have aroused widespread interest.

X.—CONCLUSION

In their first Report the Agricultural Research Council attempted to give a survey of the state of agricultural science in Great Britain in the years 1931 to 1933. A similar survey is scarcely again necessary after so short a lapse of time. Attention has therefore been directed in the main in the preceding pages to certain institutions or activities which have been the subject of special enquiry by the Council and its Committees in 1934 and 1935.

The work summarized in this Report shows that the two years under review, the third and fourth years of the existence of the Agricultural Research Council, mark an end of the opening chapter in their history.

Firstly, these years have seen the completion of the major part of the examination of the agricultural research going on in this country, an examination which the Council began on its foundation. On the whole, the Council are satisfied with the work. Many institutions and individuals are making valuable contributions to pure science or to practical agriculture or both, and no appreciable wasteful overlapping is apparent. But here and there the Council or its Committees have had to criticise, sometimes a want of clear objective and sometimes the details of some of the work. Again, in other cases, a want of co-ordination in the researches in one institution has been detected, or a lack of consultation between different institutions engaged on cognate enquiries. The Council have not refrained from plain speaking when it appeared desirable, and desire to express their appreciation of the good humour with which, for the most part, the criticism has been received, and the readiness with which changes have been made to meet it. The members of the Council venture to hope that appreciable improvement has followed, and that the nation is now getting even better value for the money spent on agricultural research.

Secondly, during the spring and summer of 1935, a reconstitution of the powers and functions of the Council has been carried through, and approved by the Committee of Privy Council for the Organisation and Development of Agricultural Research.

In the revised Provisional Note on Administrative Arrangements, often referred to as the new Concordat, the Agricultural Research Council is given explicitly power to conduct researches of its own, at centres of its own or elsewhere. While general

Parliamentary responsibility for agricultural research will remain with the Ministers responsible for agriculture, the Lord President will answer for expenditure by the Agricultural Research Council of whatever amount is approved by the Committee of Privy Council and borne on the Vote for Scientific Investigation, etc.

The responsibility of the Agricultural Research Council as advisers of the Development Commission for securing effective co-ordination of all agricultural research financed from the Development Fund is emphasized, and the duty is laid on them of submitting to the Development Commissioners an annual financial statement analysing the whole provision proposed to be charged on the Development Fund, and of advising the Development Commissioners as to the allocation of the provision actually made available by the Treasury. In addition to the normal annual grants, a provision will be included in the Departmental Estimates to cover special grants to be made from State sources to Institutions receiving maintenance grants through the Departmental Votes for such services as the Agricultural Research Council decide to assist or initiate. The Council from their own funds will restrict their grants to individuals, organisations and Institutions not aided from the Votes of the Agricultural Departments.

It will be seen that powers hitherto unused by the Council, whether covered by the first Concordat or not, are explicitly confirmed to it by the second Concordat. The Council's relations with the Agricultural Departments are thus more clearly defined, and the Council's sphere of action extended for the future.

RICHARD CAVENDISH,
Chairman of the
Agricultural Research Council.

E. J. Butler,
Secretary of the Council,
6a, Dean's Yard,
Westminster, S.W.1.

15th September, 1936.

APPENDIX I

SECOND PROVISIONAL NOTE ON ADMINISTRATIVE ARRANGEMENTS ADOPTED BY THE COMMITTEE OF PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH WITH THE CONCURRENCE OF THE TREASURY, ON THE 26th AUGUST, 1935

1. The existing general relationship of the Agricultural Departments with Agricultural Research Institutes, University Departments of Agriculture and Agricultural Colleges will continue unchanged, and grants will be made by the Agricultural Departments to these Institutions as hitherto. But as regards research grants, the Agricultural Departments will provide the Agricultural Research Council with all information at their disposal and will receive their criticism or advice. In particular, the research programmes of the Institutes and University Departments will be referred by the Agricultural Departments to the Council (together with estimates of cost) so that the Council may furnish the Departments with their comments and advice before proposals are submitted to the Treasury.

2. The Agricultural Research Council may themselves carry out agricultural research and may employ scientific and other staffs for this purpose at research centres under their own direction, or elsewhere, but if at an Institute aided by grants from an Agricultural Department, the agreement of the appropriate Department will first be obtained.

3. The Council will consult the Agricultural Departments with regard to proposals initiated by the Council, whether affecting the Institutions for which the Departments are responsible or not.

4. The Council will act as the scientific advisers of the Development Commissioners on Schemes of agricultural research, the Development Commissioners reporting as heretofore to the Treasury, when they desire to recommend expenditure.

5. As advisers to the Development Commissioners, the Agricultural Research Council will be responsible for securing the effective co-ordination of all agricultural research financed from the Development Fund. They will give attention in particular to the requirements (1) that any expansion of agricultural research is directed to the most important research needs of the industry: (2) that present and future facilities available at Research Institutes or elsewhere are utilised to the greatest advantage, and (3) that undesirable duplication of research work is avoided.

6. In connection with the preparation of Annual Estimates the Agricultural Research Council will submit to the Development Commissioners a financial statement analysing the whole provision proposed to be charged on the Development Fund for the ensuing year for agricultural research, whether recommended on the initiative of the Departments or of the Agricultural Research Council: and will if necessary, and if circumstances permit, advise the Development Commissioners as to the allocation of the provision actually made available by the Treasury.

7. Grants to Research Institutes, administered by Agricultural Departments and borne on their Votes, will so remain (unless and until the services are discontinued). In addition to the normal annual grants a

provision will be included in the Departmental Estimates to cover special grants to be made from State sources by the Departments to Institutes for such special services as the Agricultural Research Council decide to assist or initiate.

An application for special grant shall be dealt with by the Agricultural Research Council after consultation with the Department concerned and the decision thereon shall be notified by the Department. When they think it desirable, the Agricultural Research Council will, as hitherto, consult directly with Research Institutes.

8. Provision shall be made on the Vote for Scientific Investigation, etc., for the expenditure to be incurred by the Agricultural Research Council, to include the honoraria and administrative expenses of the Council, the cost of research establishments directed by the Council, and a provision, to be expended at the sole discretion of the Council, for special grants to individuals, to Institutions or to organisations other than those financed from the Votes of the Agricultural Departments.

9. The provision to be made for agricultural research, whether on the Votes of the Agricultural Departments or on the Vote for Scientific Investigation, etc., will, as heretofore, be determined by the Treasury, and, save as noted in 8 above, its application will be subject to the normal Treasury control.

10. Parliamentary responsibility for agricultural research will remain with the Ministers responsible for agriculture, but the Lord President will answer for expenditure by the Agricultural Research Council approved by the Committee of Privy Council and borne on the Vote for Scientific Investigation, etc.

11. The dividing line now drawn between expenditure financed direct by the Agricultural Departments and expenditure financed by these Departments by means of grants from the Development Fund will be retained.

12. Any questions as to the interpretation of this Note will be referred to the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

APPENDIX II

COMMITTEES OF THE AGRICULTURAL RESEARCH COUNCIL

(as at the 1st October, 1936)

STANDING COMMITTEES

Soils and Plant Nutrition

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir William Cecil Dampier, Sc.D., F.R.S.
Sir A. Daniel Hall, K.C.B., LL.D., F.R.S.
Spencer W. Mount.
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.

Plant Physiology, Breeding and Disease

Sir A. Daniel Hall, K.C.B., LL.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Joseph F. Duncan.
J. C. F. Fryer, O.B.E., M.A.
Spencer W. Mount.
Professor Sir William Wright Smith, M.A., D.ès Sc., F.R.S.E., F.L.S.

Animal Diseases

Sir Merrik Burrell, Bart., C.B.E., J.P. (*Chairman*).
W. Horner Andrews, D.Sc., M.R.C.V.S.
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
Sir Patrick P. Laidlaw, Ch.B., F.R.C.P., F.R.S.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
John Smith, O.B.E., M.R.C.V.S., D.V.H.
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.

Animal Nutrition and Breeding

Professor Sir Frederick Gowland Hopkins, O.M., D.Sc., F.R.C.P., F.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
Sir Patrick P. Laidlaw, Ch.B., F.R.C.P., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S.
Professor R. C. Punnett, M.A., F.R.S.
John Smith, O.B.E., M.R.C.V.S., D.V.H.
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.
Professor D. M. S. Watson, D.Sc., F.R.S.

Dairying and Animal Products

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S.
John Smith, O.B.E., M.R.C.V.S., D.V.H.
Professor D. M. S. Watson, D.Sc., F.R.S.

Economics

Joseph F. Duncan (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir William Cecil Dampier, Sc.D., F.R.S.
Sir A. Daniel Hall, K.C.B., LL.D., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S.
Professor F. W. Ogilvie, M.A.

Budget

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
Joseph F. Duncan.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S.
Spencer W. Mount.

COMMITTEES APPOINTED ANNUALLY

Estimates of Research Institutes

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S. (*Chairman*).
J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir William Cecil Dampier, Sc.D., F.R.S.
Spencer W. Mount.
John Smith, O.B.E., M.R.C.V.S., D.V.H.
Professor D. M. S. Watson, D.Sc., F.R.S.
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.
Joseph F. Duncan.
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.
(For Scottish Research Institutes only.)

Scholarships

Sir A. Daniel Hall, K.C.B., LL.D., F.R.S. (*Chairman*).
W. H. Andrews, D.Sc., M.R.C.V.S.
Sir Merrik Burrell, Bart., C.B.E., J.P.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., LL.D., F.R.S.
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.
John Smith, O.B.E., M.R.C.V.S., D.V.H.
Professor W. W. C. Topley, M.A., M.B., F.R.C.P., F.R.S.
Professor D. M. S. Watson, D.Sc., F.R.S.

TECHNICAL COMMITTEES

Preservation of Grass and other Fodder Crops

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*).
Thomson Close, M.B.E.
H. J. Denham, M.A., D.Sc.
H. J. Gough, M.B.E., D.Sc., F.R.S.
Leonard Harding, Ph.D., M.I.Chem.E.
Professor R. G. Stapledon, C.B.E., M.A.
J. G. Stewart, M.A., B.Sc., N.D.A., N.D.D.
Professor J. A. Scott Watson, M.C., M.A.
H. E. Woodman, M.A., D.Sc.

Insecticides and Fungicides

E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S. (*Chairman*).
W. F. Bewley, C.B.E., D.Sc.
J. C. F. Fryer, O.B.E., M.A.
R. W. Marsh, M.A.
A. M. Massee, D.Sc., F.R.E.S.
H. Martin, D.Sc., A.R.C.S., F.I.C.
Spencer W. Mount.
Professor J. W. Munro, M.A., D.Sc.
F. Tattersfield, D.Sc., F.I.C.

Helminths of Economic Importance (Plants Section)

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*).
E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.
J. Carroll, M.Sc.
J. C. F. Fryer, O.B.E., M.A.
T. Goodey, D.Sc.
Professor R. T. Leiper, M.D., D.Sc., F.R.S.
D. O. Morgan, M.Sc., Ph.D.
D. Robertson, Ph.D., B.Sc., N.D.A.
Miss M. J. Triffitt, D.Sc. (*Secretary*).
C. B. Williams, M.A., Sc.D.

Helminths of Economic Importance (Animals Section)

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*).
Professor R. A. Fisher, M.A., Sc.D., F.R.S.
G. Lapage, M.D., Ch.B., M.Sc.
Professor R. T. Leiper, M.D., D.Sc., F.R.S.
D. O. Morgan, M.Sc., Ph.D. (*Secretary*).
J. N. Oldham, B.Sc., Ph.D.
Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S.
E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.
Professor W. W. C. Topley, M.A., M.B., F.R.C.P., F.R.S.

Braxy-like Diseases in Sheep

Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E. (*Chairman*).
T. J. Bosworth, B.Sc., M.R.C.V.S., D.V.S.M.
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
T. Dalling, M.R.C.V.S.
J. Russell Greig, Ph.D., M.R.C.V.S.
A. D. McEwen, D.Sc., M.R.C.V.S. (*Secretary*).

Contagious Abortion

(Brucella abortus infection in Animals and Man)

(*Appointed in consultation with the Medical Research Council.*)

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
W. Horner Andrews, D.Sc., M.R.C.V.S.
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
Sir Weldon Dalrymple-Champneys, Bart., D.M., M.R.C.P.
Professor J. F. Craig, M.A., M.R.C.V.S.
Captain T. M. Doyle, F.R.C.V.S., D.V.S.M.
A. Gofton, F.R.C.V.S.
J. Russell Greig, Ph.D., M.R.C.V.S.
Professor R. G. Linton, Ph.D., M.R.C.V.S.
A. D. McEwen, D.Sc., M.R.C.V.S.
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S.
W. A. Pool, M.R.C.V.S. (*Secretary*).
W. J. Tulloch, O.B.E., M.D., D.P.H.
Professor G. S. Wilson, M.D., F.R.C.P., D.P.H.

Fowl Paralysis and Similar Diseases, and Coccidiosis

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*).
Professor S. L. Baker, M.R.C.V.S., L.R.C.P., Ph.D., D.P.H.
Professor S. P. Bedson, M.D., M.Sc., B.S., F.R.S.
T. Dalling, M.R.C.V.S. (*Secretary*).
N. Dobson, B.Sc., M.R.C.V.S.
P. A. Francis, O.B.E.
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E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.
J. E. Wilson, B.Sc., M.R.C.V.S.

Johne's Disease in Cattle and Sheep

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
Professor J. F. Craig, M.A., M.R.C.V.S.
G. W. Dunkin, M.R.C.V.S., D.V.H.
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S. (*Secretary*).

Swine Fever, Necrotic Enteritis, and Similar Diseases of Pigs

W. Horner Andrews, D.Sc., M.R.C.V.S. (*Chairman*).
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
C. Crowther, M.A., Ph.D.
Captain T. M. Doyle, F.R.C.V.S., D.V.S.M.
H. H. Green, D.Sc. (*Secretary*).
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Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S.
E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.
Captain W. G. Wragg, M.R.C.V.S.

Tuberculosis

(Jointly with the Medical Research Council)

J. A. Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*).
Sir Merrik Burrell, Bart., C.B.E., J.P.
L. S. T. Burrell, M.D., F.R.C.P.
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.
Professor S. L. Cummins, C.B., C.M.G.
G. W. Dunkin, M.R.C.V.S., D.V.H. (*Joint Secretary*).
A. Stanley Griffith, M.D., Ph.D.
N. F. Smith, M.D., M.R.C.S., L.R.C.P. (*Joint Secretary*).
Professor G. S. Wilson, M.D., F.R.C.P., D.P.H.

Iodine Deficiency and Thyroid Disease

(Jointly with the Medical Research Council)

Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., F.R.S. (*Chairman*).
Professor George Barger, M.A., D.Sc., F.R.S.
H. H. Green, D.Sc.
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A. W. Spence, M.B., M.R.C.P. (*Secretary*).

Members of Sub-Committees, not Members of the Council or its Committees, who served during the period covered by the present Report

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Sir John Flett, K.B.E., D.Sc., LL.D., F.R.S.
Sir Alfred Flux, C.B.
Professor J. B. S. Haldane, M.A., F.R.S.
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Professor W. Stiles, M.A., Sc.D., M.Sc., F.R.S.

APPENDIX III

GRANTS SANCTIONED BY THE AGRICULTURAL RESEARCH COUNCIL DURING THE PERIOD 1st OCTOBER, 1933, TO 30th SEPTEMBER, 1935, FOR PAYMENT FROM THE FUNDS OF THE COUNCIL.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		Plant Diseases.	
April, 1934 July, 1935	Long Ashton Research Station, University of Bristol.	Research on Insecticides and Fungicides.	£562 for period 1st July, 1934, to the 30th September, 1936.
April, 1934 July, 1935	East Malling Research Station.	Research on Insecticides and Fungicides.	£2,025 for period 1st July, 1934, to the 30th September, 1936.
July, 1935 ...	Imperial College of Science and Technology.	Development of research on the physiology of insects and the extension of research on insecticides.	£900 for one year from the 1st October, 1935.
July, 1935 ...	Farnham House Laboratory, Imperial Institute of Entomology.	Investigations into the biological control of insect pests.	£250 for one year from the 1st August, 1935.
April, 1934 July, 1935	Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Investigations into root eelworm disease of potatoes, under the co-ordination of the Council's Committee on Helminths of Economic Importance (Plants Section).	£1,850 for period 1st April, 1934, to the 31st July, 1937.
July, 1934 July, 1935	Botany School, Cambridge University.	Investigations into "Chocolate Spot" disease of beans.	£135 for one year from the 1st October, 1934.
July, 1935 ...	West of Scotland Agricultural College.	Preliminary survey of a disease of tomatoes in the south-west of Scotland.	£20.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		Plant Breeding.	
Nov., 1933 Feb., 1935	John Innes Horticultural Institution.	Cytological investigation in connection with breeding experiments with *Pyrus*, *Prunus* and *Rubus*.	£250 per annum for two years from the 1st October, 1933.
April, 1934...	Do. do.	Research on the varieties of the British flora.	£100 for one year from the 1st March, 1934.
Nov., 1934 ...	Plant Breeding Institute, Cambridge University.	New work on brassica crops.	£250 for one year from the 1st July, 1935.
		Plants (Miscellaneous).	
Nov., 1933 Nov., 1934	Imperial College of Science and Technology.	Investigations into the control of the fungus, *Byssochlamys fulva*.	£476 for period 1st November, 1933, to the 30th September, 1935.
April, 1934...	East Anglian Institute of Agriculture.	Investigations on rice grass, *Spartina townsendii*.	£50 for one year from the 1st May, 1934.
		Soils.	
Nov., 1934 ...	Macaulay Institute for Soil Research.	Extension of work at the Pot Culture Station of the Institute.	£100 (capital grant).
Nov., 1934 ...	(*a*) University College of North Wales. (*b*) Long Ashton Research Station. (*c*) Harper Adams Agricultural College. (*d*) Macaulay Institute for Soil Research. (*e*) School of Rural Economy, Oxford University.	Preparation of exhibits for the Soil Science Congress, July, 1935.	(*a*) £30. (*b*) £20. (*c*) £20. (*d*) £100. (*e*) £30.
Feb., 1935 ...	Macaulay Institute for Soil Research.	Investigations into methods of spectrographic analysis of soils.	£850 for one year from the 1st April, 1935.
July, 1935 ...	School of Rural Economy, Oxford University.	Changes in the composition and properties of clay particles during dehydration.	£300 for one year from the 1st October, 1935.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		Animal Diseases.	
April, 1934 May, 1935	(*a*) Research Institute in Animal Pathology, Royal Veterinary College.	For work under the co-ordination of the Council's Committee on *Brucella abortus* Infection in Animals and Man.	(*a*) £216 for period 1st June, 1934, to the 30th September, 1935. £20 for one year from the 1st April, 1935.
April, 1934...	(*b*) South-Eastern Agricultural College, Wye.		(*b*) £333 for period 1st June, 1934, to the 30th September, 1935.
April, 1934 March, 1935	(*c*) Department of Veterinary Pathology, Liverpool University.		(*c*) Supplementary grant of £42 for period 1st June, 1933, to the 31st May, 1934. £160 for period 1st June, 1934, to the 30th September, 1935.
April, 1934...	(*d*) Hannah Dairy Research Institute.		(*d*) £434 for period 1st June, 1934, to the 30th September, 1935.
April, 1934 Nov., 1934	(*e*) Rowett Research Institute.		(*e*) £167 for period 1st June, 1934, to the 30th September, 1935.
April, 1934...	(*f*) Animal Diseases Research Association of Scotland.		(*f*) £227 for period 1st June, 1934, to the 30th September, 1935. £67 in aid of the administrative expenses of the Scottish Committee during the same period.
Nov., 1933 ...	(*a*) Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Research on sheep blowflies.	(*a*) £107 for period 1st October 1933, to the 28th February, 1934.
Feb., 1934 Nov., 1934	(*b*) University College of North Wales, Bangor.		(*b*) £879 for period 1st March, 1934, to the 30th September, 1935.
July, 1934 ...	(*c*) Natural History Department, University of Aberdeen.		(*c*) £75 for one year from the 1st June, 1934.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
Animal Diseases—cont.			
Nov., 1933 May, 1935	(*a*) Molteno Institute, Cambridge University.	Investigations into fowl paralysis, under the co-ordination of the Council's Committee on Fowl Paralysis and Allied Diseases, and on Coccidiosis.	(*a*) £338 for period 1st January, 1934, to the 30th September, 1935.
Nov., 1933 May, 1935	(*b*) Manchester University.		(*b*) £175 for period 1st January, 1934, to the 30th September, 1935.
Feb., 1934 July, 1934 Feb., 1935	National Institute for Research in Dairying, University of Reading.	Investigations into the viability of the bovine tubercle bacillus under natural conditions, under the co-ordination of the Joint Committee on Tuberculosis of the Agricultural Research Council and the Medical Research Council.	£447 for period 1st December, 1933, to the 31st December, 1935.
Nov., 1934 May, 1935	Institute of Animal Pathology, Cambridge University.	Investigations on BCG. vaccine, under the co-ordination of the Joint Committee on Tuberculosis of the Agricultural Research Council and the Medical Research Council.	£3,107 for period 1st October, 1934, to the 31st March, 1936.
Sept., 1934...	—	Comparative tests with different samples of Johnin carried out at the farm laboratories of the National Institute for Medical Research, on behalf and under the co-ordination of the Council's Committee on Johne's Disease in Cattle and Sheep.	£118.
Nov., 1934 ...	South-Eastern Agricultural College, Wye.	Investigations into Johne's disease of sheep under the co-ordination of the Council's Committee on Johne's Disease in Cattle and Sheep.	£236 for a period of two years from the 1st January, 1935.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
	Animal Diseases—cont.		
Nov., 1934 ...	South-Eastern Agricultural College, Wye.	Investigations into the control of "struck" of sheep by means of a specific bacterial vaccine under the co-ordination of the Council's Committee on Braxy-like Diseases of Sheep.	£60 for one year from the 1st October, 1934.
Nov., 1934 ...	Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Examination of various chemical substances which might have an anthelmintic action upon intestinal nematodes, especially in sheep, under the co-ordination of the Council's Committee on Helminths of Economic Importance (Animals Section).	£500 for one year from the 1st August, 1935.
Nov., 1934 ...	Rowett Research Institute.	Investigations into intestinal parasites of sheep under the co-ordination of the Council's Committee on Helminths of Economic Importance (Animals Section).	£230 for one year from the 1st October, 1934.
Feb., 1935 ...	Institute of Animal Pathology, Cambridge University.	Investigations into braxy-like diseases of sheep under the co-ordination of the Council's Committee on Braxy-like Diseases of Sheep.	£1,050 for one year from the 1st April, 1935.
Nov., 1934 ...	Veterinary Laboratory, Ministry of Agriculture and Fisheries.	Investigations into the use of disinfectants against swine fever virus under the co-ordination of the Council's Committee on Swine Fever and Similar Diseases.	£500 (provided by a grant from Imperial Chemical Industries, Limited).
April, 1935...	Institute of Animal Pathology, Cambridge University.	Investigations into swine erysipelas under the co-ordination of the Council's Committee on Swine Fever and Similar Diseases.	£400 for one year from the 1st April, 1935.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		Animal Diseases—cont.	
Feb., 1935 ...	Harper Adams Agricultural College.	Investigations into the possibility of curing "Blackhead" in turkeys by the use of sodium hypochlorite (Chlor-san) and carbon tetrachloride.	£50 for one year from the 1st April, 1935.
July, 1935 ...	Royal (Dick) Veterinary College, Edinburgh.	Research on disabling diseases of horses.	£332 for one year from the 1st October, 1935.
		Animal Breeding.	
Nov., 1933 April, 1934	Institute of Animal Genetics, University of Edinburgh.	Research on wool problems.	£804 for period 1st October, 1933, to the 31st March, 1935.
		Animal Nutrition.	
Nov., 1934 May, 1935	School of Rural Economy, Oxford University.	Investigations into problems of sheep nutrition.	£232 for a period of two years from the 1st October, 1934. Supplementary grant of £46 in respect of period 1st October, 1933, to the 30th September, 1934.
		Animals (Miscellaneous).	
April, 1934 July, 1934 July, 1935	Bureau of Animal Population, Oxford University.	In aid of the general work of the Bureau.	£930 for period 1st February, 1934, to the 30th September, 1936.
		Dairying.	
May, 1935 ...	National Institute for Research in Dairying, University of Reading.	Experimental work on beet taint in milk.	£320 for period 1st April, 1935, to the 31st August, 1936.
		Miscellaneous.	
Nov., 1933 Nov., 1934	Rothamsted Experimental Station.	Investigations into foul brood disease of bees.	£375 for period 1st April, 1934, to the 30th September, 1935.
May, 1935...	Council's Committee on the Preservation of Grass and Other Fodder Crops.	For investigations under the co-ordination of the Committee.	£1,000.

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